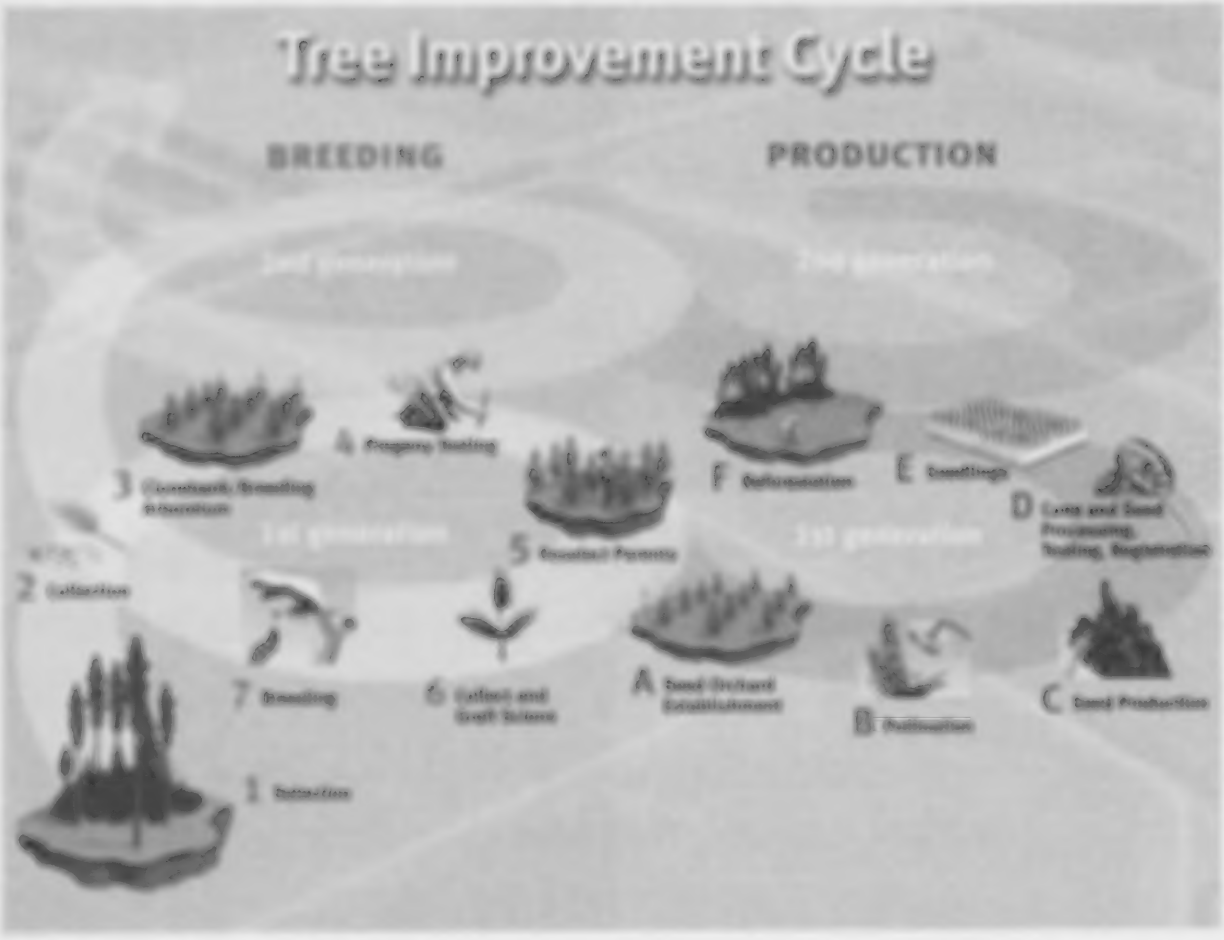


2005/2006

Forest Genetics Council of BC

Tree Improvement Program Project Report

Forest Genetics Council of BC

Tree Improvement Program Project Report

Coordinated and compiled by:
Beacon Hill Communications Group Inc.

and

Roger Painter
Tree Improvement Branch
British Columbia Ministry of Forests

Acknowledgements

We're now into year nine of this Program and we have new challenges to face. Mother Nature has provided us with a huge pressure in the way of the devastation from Mountain Pine Beetle (MPB) attacks. The Tree Improvement Program has proven to be one of the most enduring and successful partnerships sponsored by our Provincial Government and we are gearing up to answer this test. We have worked hard to meet the goals that were set back in 1997 and for the most part we continue to be on track and grow as a program. A new revitalized Seed Pest Management Technical Advisory Committee has initiated a program and hired staff to answer problems about seed pests by investing in longer-term research and problem solving in that vital area. The Centre for Gene Conservation work continues on cataloguing and issues related to another big challenge, climate change. The other sub-programs Breeding and Testing, Gene Resource Information Management, Extensions and Communications, the Operational Tree Improvement Program, and SelectSeed provide a comprehensive operational program for improved seed supply.

The Forest Investment Council continues to recognize the value of investing in tree improvement. At the same time, with that come expectations for the Forest Genetics Council to address MPB and climate change as they relate to our discipline. But Council has good solid management processes which will hold us in good stead as we reach for answers to the new challenges.

I would like to acknowledge the Project Leaders for completing their contributions to this report. This publication continues to provide an excellent review of our efforts and receives numerous compliments within the forest industry on the successes of Tree Improvement. My congratulations to you all for an excellent ninth annual report. I hope you enjoy it. My sincere thanks for the hard work of our editorial review team for taking the time to look over our submissions. They include Diane Douglas, Keith Thomas and Chris Walsh.

Our sincere thanks to Jack Woods, CEO of Select Seed for his valuable contribution to the centre collage. SelectSeed has now finished what was hoped to be the final stage of providing overall coverage for seed orchard seed for the province. With MPB in the offing we may still have a way to go. The front and back covers of this year's report are work from our Extension program where we have created an updated version of the Tree Improvement Cycle.

Again, my thanks to all those who have worked on this program in the past year and over the past ten years, including the review committees, species committees and various TAC's. You are the reason that this program has a strong technical direction. To all the Project Leaders, I hope 2006/2007 is as successful as the year before.

Roger A. Painter
Tree Improvement Co-ordinator
Forest Genetics Council

Forest Genetics Council Co-chairs

Once again we thank the many industry and government staff who contribute to the provincial gene resource management program for their cooperation and dedication over the past year. Although forestry in BC is changing quickly, there is a consistent and solid base of support for tree improvement, and a well-established planning process is in place.

During the 2005/06 fiscal year, substantial progress was made in several important areas:

- The Forest Genetics Council completed and started the implementation of Chief Forester Standards for Seed Use in support of the new *Forest and Range Practices Act*. The Standards consolidate existing policy, guidelines, and practices and result in efficiencies for both industry and government stakeholders. Many members of the council and its affiliated committees contributed to and improved the Standards during the past year.
- The council completed ongoing changes in council membership, allowing long-serving councilors a rest and bringing new energy to gene resource management in BC.
- The provincial Chief Forester offered a Vision and Framework for Sustainable Forest Management that integrates the FIA – Tree Improvement Program and continues to call upon the council's long-term goals for increased seed quality and seed production in seed orchards.

The coming year presents new challenges for council. The Mountain Pine Beetle (MPB) effects on forest management in the near-, mid- and long-term demand further analysis of council assumptions in seed supply planning. This includes both tactical and strategic consideration of supplies of wild, improved provenance, and select seed contributions to seed needs. Information management systems that allow for these complex analyses of supply and demand are showing themselves to be critical in this process. In addition, MPB damage to, or potential to damage, seed orchard production is becoming a significant factor in responding to MPB needs. Your program co-chairs are confident that council, the Ministry, and our associated committees will continue to meet these challenges in 2005/06.

John Elmslie
Industry Co-chair

Dale Draper
Ministry Of Forests
Co-chair

The Forest Genetics Council Co-Chairs invite you to review the programs and projects described in this report and return any questions or comments to:

TIP Program Administrator
Ministry of Forests and Range
Tree Improvement Branch
PO Box 9518 Stn Prov Govt
Victoria, B. C. V8W 9C2

Further Tree Improvement information can be found at our Web sites:

Forest Genetics Council	http://www.fgcouncil.bc.ca
Ministry of Forests and Range, Tree Improvement Branch	http://www.for.gov.bc.ca/TIP/index.htm
Ministry of Forests and Range, Research Branch	http://www.for.gov.bc.ca/research/

Table of Contents

Acknowledgements ii
Forest Genetics Council Co-chairs iii
Tree Improvement in British Columbia ix
Ministry of Forests and Range Program Overview ix
Forest Genetics Council of B.C. ix
FIA – Tree Improvement Subprograms x
1.0 Expansion of Orchard Seed Supply Subprogram (SelectSeed Company Ltd.) 1
2.0 Gene Resource Information Management 2
3.0 Centre for Forest Gene Conservation (CFGC) 4
4.0 Tree Breeding 5
4.1 Coastal Douglas-fir 5
4.2 Sitka Spruce 7
4.3 Western Hemlock 7
4.4 Western Redcedar Breeding Program 9
4.5 Yellow-cedar Breeding Program 10
4.6 Coastal White Pine 11
4.7 Coastal Broadleaf Genetics Programs 12
4.8 Interior Douglas-fir Tree Breeding 13
4.9 Interior Spruce Tree Breeding 14
4.10 Western larch Tree Breeding 15
4.11 Lodgepole, White and Ponderosa Pines and Interior Broadleaved Species Work in 2006 ... 16
5.0 Operational Tree Improvement: The Ninth Year in Review 19
5.1 Orchard Projects 20
5.1.1 Saanich Forestry Centre 20
5.1.2 Sechelt Seed Orchard 23
5.1.3 TimberWest Mt. Newton Seed Orchard 24
5.1.4 Bowser Seed Orchards 26
5.1.5 Kalamalka Seed Orchards 27
5.1.6 Vernon Seed Orchard Company (VSOC) 28
5.1.7 PRT Armstrong – Grandview Seed Orchards 30
5.1.8 Eagle Rock Seed Orchard, Tolko Industries 32
5.1.9 Prince George Tree Improvement Station 32
5.1.10 Skimikin Seed Orchards 34
5.1.11 Kettle River Seed Orchard Co. 36
5.2 Technical Support Projects 36
5.2.1 Cone and Seed Pest Management – Interior Operations 36
5.2.2 Western Redcedar Pollen Monitoring, Saanich Peninsula and Sechelt 37
5.2.3 Douglas-fir and Western Redcedar Cone and Seed Insect Pest Monitoring Services to Coastal Conifer Seed Orchard Managers. 39

5.2.4 Development of Pollen Management Guidelines for Yellow-cedar 40
5.2.5 Operational Crown Management Trials in Various Orchards: Interior Spruce "High-density" Seed Orchard 620 and Interior Douglas-fir Orchard 324 40
5.2.6 Testing the Effects of Modified Irrigation Delivery Systems in NE Mid-Interior Spruce Seed Orchard 305 and Interior Lodgepole Pine Seed Orchard 307 42
5.2.7 Enhancing Seed Production in North Okanagan Lodgepole Pine Seed Orchards 43
5.2.8 Increasing Quality, Genetic Gain, and Quantity of Yellow-cedar Cuttings 46
5.2.9 Damage potential of Leptoglossus occidentalis on Sx, Lw, Pw, and Fdi 48
5.2.10 Effect of Selfing and Flowering Phenology on Seed Production in Yellow-cedar Seed Orchards 48
5.2.11 Crown Pruning Technique for North Okanagan Lodgepole Pine Seed Orchards 49
5.2.12 Western Hemlock/Sitka Spruce Pollen Monitoring, Saanich Peninsula 51
6.0 Extension and Communications 53
6.1 Extension Technical Advisory Committee (ETAC) Subprogram 53
7.0 Seed Pest Management 56
Appendix 1 FGC Seed Planning Units 57
Appendix 2 Tree Species 58
Appendix 3 Discussions by Tree Species 59
Appendix 4 Authors and Species Topic 60
Appendix 5 Author Contact List 61

List of Figures

Figure 1. Relationship between FGC Strategic Plan, FIA-TIP, and participants in various forest gene resource management areas x
Figure 2. Schematic of organizational relationships among FGC, FIA, SelectSeed and seed users 1
Figure 3. Relationship between western redcedar needle monoterpenes and browse pressure 10
Figure 4. Relationship between best linear predicted clonal values 11
Figure 5. Proportion of trees killed by *Armillaria* within Interior Douglas-fir families 13
Figure 6. Mean daily western redcedar pollen catch for five stations on the Saanich peninsula 39
Figure 7. Mean daily western redcedar pollen catch for three stations at Sechelt 39
Figure 8. 2005 mean total seed per cone at Kalamalka 44
Figure 9. 2005 mean filled seed per cone in each of four cultural blocks at Kalamalka 44
Figure 10. 2005 mean first- and second-year cone numbers in four cultural blocks at Kalamalka 44
Figure 11. Mean total seed per cone with insect protection for four cultural blocks at Kalamalka 44
Figure 12. Mean filled seed per cone with insect protection for four cultural blocks at Kalamalka 45
Figure 13. Mean first-year cone numbers for each of four cultural blocks at Kalamalka 45
Figure 14. Mean second-year cone numbers for each of four cultural blocks at Kalamalka 45
Figure 15. Mean pollen-cone cluster numbers for each of four cultural blocks at Kalamalka 45
Figure 16. Pollen load (grains/mm^2) summary for the shedding period at Kalamalka 45
Figure 17. Whole tree seed cone estimates by topping height and lateral pruning treatments 50
Figure 18. Mean branch seed-cone counts by topping height and crown position 50

Figure 19. Mean filled seed per cone by topping height and lateral pruning treatment for insect protected cones 50
Figure 20. Mean filled seed per cone by topping height and crown position for insect protected cones 50
Figure 21. Mean seed cone dry weight by topping height and crown position for insect protected cones 50
Figure 22. Western hemlock pollen shed on the Saanich peninsula 52
Figure 23. Sitka spruce pollen shed on the Saanich peninsula, 2005 52

List of Tables

Table 1. Heights and heritabilities of phase-one GCA tests planted on four sites 6
Table 2. Number of projects and funding by region 19
Table 3. Number of project/area of investment 20
Table 4. Orchard composition activities by project 27
Table 5. Pollen management activities by project 28
Table 6. Summary of VSOC 2005 OTIP activities 29
Table 7. Mean western redcedar pollen load for two monitoring sites and two monitoring years 38
Table 8. Average infested scales per conelet counts (ISCC) for five of eleven coastal BC Douglas-fir seed orchards 40
Table 9. Treatments applied to ramets in PSI orchard 124 in 2005 41
Table 10. Treatments applied to ramets in the spruce micro orchard 41
Table 11. Compare shoot growth measurements between irrigation treatments 42
Table 12. Compare cones from PSI orchard 307 irrigation trial 42
Table 13. Heat and vapour pressure deficit sums for the period of pre-pollination at Kalamalka 45
Table 14. Heat and vapour pressure deficit sums for the period of pollination at Kalamalka 45
Table 15. Heat and vapour pressure deficit sums for the period of fertilization and early embryo development at Kalamalka 45
Table 16. Heat and vapour pressure deficit sums for the period of seed-cone differentiation at Kalamalka 46

List of Plates

Plate 1. Seed map 3
Plate 2. Scion selection on Hurley River 6
Plate 3. Hemlock breeding arboreta 8
Plate 4. Root/shoot measurements for looking at the allocation of seedling resources 8
Plate 5. Western redcedar greenhouse breeding orchard at Cowichan Lake Research Station 9
Plate 6. Deer browsing at Olympia National Wildlife Centre Field Station 9
Plate 7. Fifteen-year-old yellow-cedar provenance study at Eve River 10
Plate 8. Three seedlots from the BC/Alberta climate change project 14
Plate 9. A seedling planted at the Dawson Creek climate change site 15
Plate 10. The seedling lift for the BC/Alberta climate change project 15
Plates 11 and 12. Vicky Berger with White pine blister rust resistant seed orchard parent tree 16
Plates 13 and 14. John Murphy and Nicholas Ukrainetz selecting PSI seed orchard parents 16
Plate 15. Nick Ukrainetz at a PSI Orchard Elite vs Wild Seedlot demonstration site 17

Plate 16. Nick Ukrainetz and a Yellow Cypress clonal crown fire variation demonstration 17
Plates 17 and 18. "Karaleka" Silver Birch from Finland, 8 years at Skimikin Seed Orchard 17
Plate 19. Future Forest services Ltd. measuring a 9 year old wind-pollinated family trial of paper birch 18
Plate 20. Measuring the 47 seed-source paper birch genecology trial at Skimikin Seed Orchard 18
Plate 21. Cottonwood stands, Vernon Commonage 18
Plates 22 and 23. John Murphy, Vicky Berger and Nicholas Ukrainetz selecting galt-free seed orchard parent trees 19
Plate 24. Vicky Berger in a hybrid poplar clonal trial planted 1997 in the Kootenay River Valley 19
Plate 25. PGFTIP Douglas-fir breeder Michael Stoehr at a Jordan River Operation Fdl test site 21
Plate 26. Western redcedar cones, including some damaged cones, as seen in early July 21
Plate 27. Sitka spruce flowers are isolated in bags for Dr. John King's breeding program 22
Plate 28. The SPC Douglas-fir crop yields high-gain seed to the reforestation programs 22
Plate 29. Georgina Sampson grafts selected high-elevation western hemlock scion to rootstock 23
Plate 30. Developing western hemlock cones in orchard 170 yield seed of 16% volume gain 23
Plate 31. Pollen cones on western hemlock display microsporophyll separation prior to pollen shed 23
Plate 32. Paul Bartonetti applies gibberellin acid to the foliage of western redcedar 23
Plate 33. These developing Sitka spruce cones produced seed for weevil-resistant Sitka spruce reforestation programs 23
Plate 34. The Cw project (which puts up potential Cw selections) 24
Plate 35. Douglas-fir cone harvest with person-lift at Mt. Newton Seed Orchard 25
Plate 36. Applying GA$_{4/7}$ to Douglas-fir 28
Plate 37. Pest management in Douglas-fir 28
Plate 38. Planting spruce rootstock in the new hoophouse 29
Plate 39. Flower induction – GA stem injection in orchard 114 (2). 31
Plate 40. Collecting pollen using backpack vacuum, orchard PA 313. 31
Plate 41. Aerial photo of PGTIS. 32
Plate 42. Cone picking with a giraffe in the Willow-Bowron 220 orchard. 33
Plate 43. Aerial photo of PGTIS. 34
Plate 44. Bottom branch pruning/chipping 35
Plate 45. Topping in the Willow-Bowron 220. 35
Plate 46. The crew with the 2005 cone crop. 36
Plate 47. Margaret Lapse picking in orchard 200 (Bx Low Sx) 36
Plate 48. Mountain pine beetle attacked tree near the seed orchards 37
Plate 49. Lauri Farrell bagging cone sacks 37
Plate 50. Karen Turner picking in orchard 204 PG High Sx) 37
Plate 51. Topped trees in heavily rogued orchard 209 (Prince George High spruce). 37
Plate 52. The anti-aggregation pheromone verbenone being used in an efficacy trial. 37
Plate 53. Red alder pollen 38
Plate 54. Redcedar pollen 38
Plate 55. Inspecting yellow-cedar cuttings for donor production 46
Plate 56. Yellow-cedar cull-based donor hedges 46
Plate 57. Top pruning yellow-cedar donors 46
Plate 58. Potted yellow-cedar donors 47
Plate 59. Potting up yellow-cedar cuttings for donor production 47
Plate 60. Crown management workshop led by Dr. Joe Webber. 53
Plate 61. Crown pruning workshop, November, 2005 53
Plate 62. A presentation by Dr. Joe Webber at the coastal pollen management workshop. 53

Tree Improvement in British Columbia

Ministry of Forests and Range Program Overview

Forest gene resource management encompasses the conservation, controlled use, and enhancement of genetic resources of forest tree species and related communication and education activities. The Forest Genetics Council of British Columbia (FGC) coordinates a provincial forest gene resource management program that is implemented by stakeholders in the forest industry, the Ministry of Forests and Range (MoFR), Canadian Forest Service (CFS), and universities.

The Forest Investment Account (FIA) is a major funding agency for forest gene resource management in British Columbia. Through the Tree Improvement Program (TIP), FIA invests in forest gene resource management activities that support its objectives and are complementary to existing government and industry activities.

The FIA BC Tree Improvement Program is guided by strategic and annual business plans prepared by the FGC.

Forest Genetics Council of B.C.

The Forest Genetics Council of British Columbia (FGC) is a multi-stakeholder group representing the forest industry, the Ministry of Forests and Range (MoFR), Canadian Forest Service (CFS), and universities. Council's mandate is to champion forest gene resource management in British Columbia, to oversee strategic and business planning for a co-operative provincial forest gene resource management program, and to advise the province's Chief Forester on forest gene resource management policies. FGC members provide strategic direction to the provincial forest gene resource management program. FGC Technical Working Committees (TWCs) provide technical and policy information to Council and contribute to the development of FGC plans and associated budgets.

Council's goal is to maximize the economic benefits from tree improvement gains in wood quality, quantity, and pest tolerance by supporting a gene conservation program, developing long-term production capacity, doubling the average volume gain of select seed, and increasing the amount of select seed used. The FGC Business Plan defines the annual set of activities and associated budgets to achieve this goal.

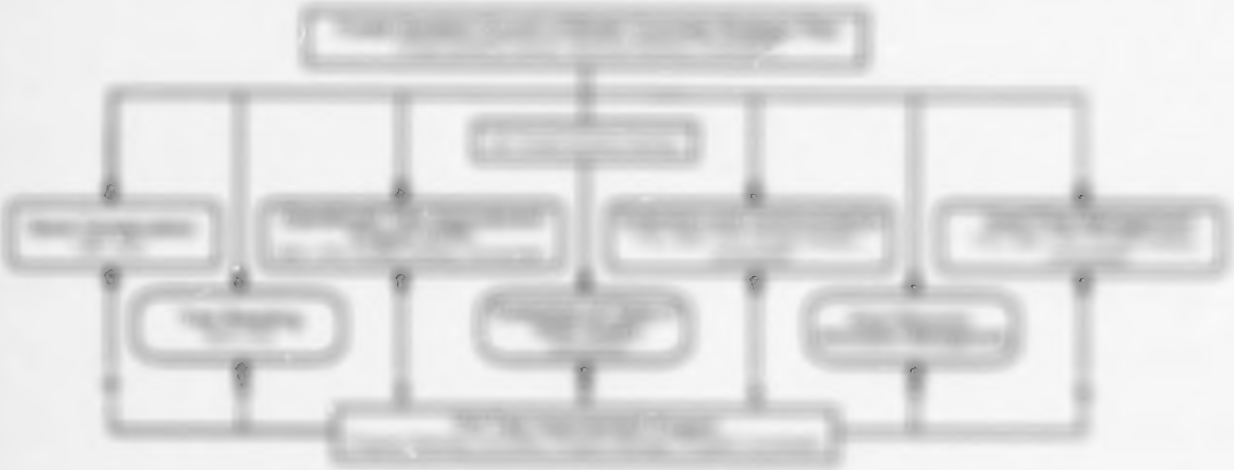
Forest gene resource management is a co-operative effort. In broad terms, the MoFR leads tree breeding activities and private industry leads operational production of reforestation materials. The Canadian Forest Service, MoF Research Branch, and universities undertake research supporting tree improvement, while private institutions focus on applied research related to operational production.

"Select" refers to seed that comes from breeding programs that select from wild stands the trees with superior characteristics for growth, strength, or pest resistance. "Seed" as used here refers to all collected reforestation materials, including vegetative propagules. The Forest Genetics Council does not support genetic engineering, and no genetically modified materials are used for forest land reforestation in British Columbia.

FIA – Tree Improvement Subprograms

[redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]



[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

[redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

trends are based on information extracted from the Reporting Silviculture and Land Status Updates system (RESULTS), Forest Tenure Administrative Status (FTAS) and the Seed Planning and Registry system (SPAR).

- SPAR on-line HELP screens were developed to assist clients in seedlot registration. SPAR/SeedMap training materials were also developed to support the new Chief Forester's Standards for Seed Use. Self-serve training is now available on-line to assist clients in using GIS map viewer tools such as iMap BC and MapWave. The SeedMap tool set follows a similar format to iMapBC and MapWave. Self-serve training can be accessed at: http://gww.for.gov.bc.ca/his/gis/training/iMapBC_selfserve.htm.

Plate 1. SeedMap.

3.0 Centre for Forest Gene Conservation (CFGC)

Sally Aitken

The research activities of the Centre for Forest Gene Conservation in support of the gene conservation objective of the Forest Genetics Council fall into four primary categories: cataloguing the protection of genetic diversity for forest tree species in British Columbia; predicting the response of forest tree populations to climate change; developing an overall gene conservation strategy for BC; and gaining knowledge about the genetics and the conservation needs of minor species. While the goal of this work is to insure that the forest genetic resources of British Columbia are well protected and not to publish papers, the review of this work by other scientists and the acceptance of papers for publication validates our approaches and the quality of our work.

CATALOGUING PROTECTION

The *in situ* conservation status of 50 forest tree species by BEC zone was published (Hamann et al. 2005), and concluded that the provincial Protected Areas Strategy provides genetic protection for most species in most ecological zones. Christine Chourmouzis initiated a longer, more detailed technical report combining *in situ*, *ex situ*, and *inter situ* conservation status and making recommendations for species in specific geographic areas or ecological zones that need ground truthing and additional protection. This report will be completed in 2006-07.

CLIMATE CHANGE

ClimateBC, the widely used model developed by CFGC staff and David Spittlehouse, MoF&R, was updated by CFGC Assistant Director Tongli Wang and published in the *International Journal of Climatology* (Wang et al. 2006). A web-based version was released publicly (on www.genetics.forestry.ubc.ca/cfgc). An analysis of the Illingworth lodgepole pine provenance trials to determine genetic responses to increased mean annual temperature was completed and has been accepted by the journal *Global Change Biology* (Wang et al.). This study concludes that mild warming will increase overall lodgepole pine productivity, but beyond mild warming, overall productivity under current seed transfer policy will decrease. However, there are opportunities to increase productivity in both current and future climates by optimizing deployment of highly productive provenances with a wide ecological amplitude. Pia Smets completed a seedling experiment exposing class B, B+, and A seed from different SPI to different temperature regimes in growth chambers that generally supports the analysis of the field trials. MSc student Sierra Curtis-McLane initiated a project in 2005 to study year-to-year variation in growth rings compared to inter-annual climatic variation in the Illingworth provenance trial to determine the response of trees from different populations to climatic extremes. The climate change research has been funded by BIOCAP Canada and NSERC as well as by the FIA through the FGC.

CONSERVATION STRATEGY

An overall conservation strategy for forest genetic resources in BC will form part of the technical report underway on the status of gene conservation for all species. *In situ* protection thresholds for gene conservation have been developed for that report, based on genetic theory. The final part of the research of Washington Lapare on sampling strategies for capturing genetic diversity in *ex situ* collections modeled the effects of the number of individuals sampled and the geographic area those individuals are sampled from. A manuscript describing this work was completed and submitted to the journal *Heredity*. The PhD work of Makiko Mimura (mostly funded by NSERC) identified the importance of conserving peripheral, disjunct populations. Isolated peripheral populations of Sitka spruce are actually better adapted than continuous, peripheral populations despite higher levels of inbreeding. These populations may be well positioned to fuel adaptation to climate change.

MINOR SPECIES

Whitebark pine has been a focus of our program since the inception of the CFGC. The PhD research of Andy Bower on the genecology of this species and the interactions between inbreeding and both fitness and blister rust is nearing completion. In the past year, seed transfer guidelines for whitebark pine have been developed, and these will be key in designing deployment strategies for restoration for seedlings that have putative resistance to white pine blister rust. Seasonal and geographic variation in cold hardiness has been analyzed (Bower

and Aitken, in press), as have the effects of inbreeding and white pine blister rust on genetic structure (Bower and Aitken, submitted). Two projects were initiated on minor, broadleaved species. Karolyn Keir (MSc student) is investigating core-peripheral genetic structure and mating system in Pacific dogwood (*Cornus nuttallii*), which, unlike the conifers we have previously studied, is bird dispersed and insect dispersed. MSc student Colin Huebert is studying adaptive variation and potential for adaptation and migration in Garry oak (*Quercus garryana*). He will be collecting acorns for a common garden experiment in the late summer and fall of 2006.

PUBLICATIONS IN 2005-06

Bower, A.D. and S.N. Aitken. Changes in genetic structure of whitebark pine (*Pinus albicaulis* Engelm.) associated with inbreeding and white pine blister rust infection. Conservation Genetics. Submitted April 2006.

Bower, A.D. and S.N. Aitken. Genetics of cold hardiness in whitebark pine. Can. J. For. Res. In press (accepted Feb. 2006).

Gapare, W.J., A.D. Yanchuk and S.N. Aitken. Optimal sampling strategies for capture of genetic diversity differ between core and peripheral populations of *Picea sitchensis* (Bong.) Carr. Submitted to Heredity, September, 2005. Under revision.

Gapare, W.J. and S.N. Aitken. 2005. Strong spatial genetic structure in peripheral but not core populations of Sitka spruce (*Picea sitchensis* (Bong.) Carr.). Molecular Ecology 14: 2659-2667.

Gapare, W. J., S.N. Aitken and C.E. Ritland. 2005. Genetic diversity of core and peripheral Sitka spruce (*Picea sitchensis* (Bong.) Carr.) populations: implications for conservation of widespread species. Biological Conservation 123: 113-123.

Hamann, A., P. Smets, A.D. Yanchuk and S.N. Aitken. 2005. An ecogeographic framework for *in situ* conservation of forest trees in British Columbia. Can. J. For. Res. 35: 2553-2561.

Wang, T., A. Hamann, D. Spittlehouse and S.N. Aitken. 2006. Development of scale-free climate data for western Canada for use in resource management. International Journal of Climatology 26: 383-397.

Wang, T., A. Hamann, A.D. Yanchuk, G.A. O'Neill and S.N. Aitken. Use of response functions in selecting lodgepole pine populations for future climates. Global Change Biology. Submitted Feb 2006 (accepted April 2006). In press.

4.0 Tree Breeding

4.1 Coastal Douglas-fir

Michael Stoehr, Keith Bird, Clint Hollefreund

LOW-ELEVATION COASTAL DOUGLAS-FIR (SPU 01)

The four first-phase GCA tests planted in 1999 for third-generation selections and breeding were measured and data were analyzed. Based on these results, the best three families in each of eight sublines were (forward) selected in a full-sib family block farm-field test. Scions were collected from the best three individuals of each family and grafted onto compatible root stock.

In the late winter of 2006, seedlings in the third phase of subline testing were outplanted in the Was area, near Powell River, near Jordan River, outside Chilliwack, at Snowden, and near Mesachie Lake. Four GCA tests were made containing half-sibs of each parent in the test (pollinated by a common polymix), and two sites containing full-sib blocks (5x5) of parents within each of eight sublines were tested. It is anticipated that the last phase of this testing will be planted in two years.

In co-operation with UVic (B. Hawkins), a study was initiated to characterize full-sib families randomly selected from phase three testing. Vegetative phenology, growth characteristics, frost hardiness, and nutrient uptake will be studied in this short-term test established on a farm-field and operational test site.

In co-operation with a visiting scientist (Bill Parker, Lakehead University), historic provenance data were re-analysed with special interest in seed movement under the predicted conditions of various climate-change models. This work will also be useful in determining seed transfer of low-elevation coastal seed to higher elevations.

COASTAL-INTERIOR TRANSITION ZONE (SUB-MARITIME) (SPU 19)

Three progeny tests to evaluate parents in orchard 181 for backward selections were established in the Pemberton and D'Arcy areas in the spring of 2005 at mid to high elevations. The tests were established using the alpha design with 30 replications with offspring from the orchard clones (pollinated with a polymix). In the early winter of 2006, forward selections were made in the EP 1200 genecology test at Railroad River

(elevation 1100 m) based on family performance on four transition zone test sites and on within-family performance at the selection site. A total of 40 scions were collected from a total of 20 selections and subsequently grafted onto compatible rootstock. These forward selections will be incorporated into orchard 181 after the orchard is rogued based on the polymix progeny tests.

Site (number of seedlings)	Height Mean (standard deviation)s	Heritability Individual	Family
Buckley Bay (2343)	299.9 (77.9)	.12	.42
Canoe (1950)	497.6 (106.0)	.22	.55
Noomas (1760)	422.8 (76.3)	.26	.56
Snowden (2015)	343.0 (81.9)	.31	.65

Table 1. Heights and heritabilities of phase-one GCA tests planted on four sites.

Plate 2. Scion selection on Hurley River.

4.2 Sitka Spruce

John King, Dave Ponsford

WEEVIL RESISTANCE PROGRAM

We are currently (April 2006) establishing the second phase of the F_1 breeding program – weevil resistance. Parents were designated by their phenotypic resistance to the weevil and their source (mainly Haney or Big Qualicum). Some susceptible parents were also used. This year's trials are being put in on North Vancouver Island, and again we are putting one of the sites on the Queen Charlotte Island — to act as a weevil-free control. This year we have sowed the last of the OP collections from around the "Big Qualicum" area. We also are establishing high-elevation trials this spring. This material, carried over from last year because of growing problems, hopes to better define elevational deployment guidelines for Sitka spruce.

Selection and breeding work continues, but our focus in the future for the breeding program will be to identify parents for specific traits. We are completing (April 2006) a more detailed microscopic evaluation of most of our breeding parents for putative resistant mechanisms. This is particularly valuable for "constitutive" types of mechanisms such as sclereid cells or constitutive resin cells, but we are also attempting to assess them for "inducible" mechanisms, mainly traumatic resin cell production.

Besides the continued help from Dr. René Alfaro's team at the Canadian Forestry Service (including George Brown's after-retirement involvement), we also are working on projects with Joerg Bohlmann and Kermit Ritland in their Genome BC project from UBC.

Ongoing trial assessments for weevil attack have continued, including some of the hazard assessment trials. This series of trials was established to test resistance over a variety of ecological and potential weevil hazard areas. The main objective is to aid in determining deployment guidelines.

OTHER COMPONENTS – QCI, NW HYBRID PROGRAM

The Queen Charlotte program allows us to assess Sitka growth free from weevil attack. It also supports the Seed Orchard Program (SO 142 and its replacement). Our major difficulty has been in getting "free-to-grow" conditions, in this case not from weevil or brush but from deer browse, and a good deal of our maintenance effort has been on browse protection. This year, thanks to this maintenance effort, most trials are now 'free-to-grow," and we are currently completing a major measurement of some of our QCI sites. We hope to finish up with all these older "weevil-free'" assessments in the coming year.

The transition program is designed mainly to test seed transferability in a very environmentally heterogeneous area with pressures from both frost and weevil. Last year we completed a basic five-year height and survival assessment. We used this information to have a very successful extension trip with Northwest foresters. In the coming year we plan on doing a fairly comprehensive weevil assessment and will also be able to use this factor in determining suitability of seed transfer.

4.3 Western Hemlock

Charlie Cartwright

LOW-ELEVATION MARITIME HEMLOCK (SPU 03)

The focus of the low-elevation (<600 m) hemlock program is on the launch of third-generation breeding. Second-generation orchards based on backward selection of parents from the Hemlock Tree Improvement Cooperative are now in production, with the best seedlots rated to 16% volume gains at rotation. Tests based on controlled crosses of trees acquired through the co-op have all had age 5 heights measured, and preliminary selections for the third-generation program have been made and grafted into breeding arboreta (Plate 3). Final selection will be based on age 10 data. So far, the earliest series of second-generation tests has had age 10 height and diameter measured, with two series to go. Some third-generation breeding has commenced, as well as studies of cone induction involving small potted clones. Due to inbreeding considerations and questions as to the level of adaptation of parents from Oregon and southern Washington state, final selections cannot be made until all series of tests are measured at age 10.

In support of the effort to increase genetic gain through the main breeding program, provenance testing is ongoing for the purpose of establishing safe boundaries for seed transfer. To this end two new tests were out-planted at the northern extent of the

range in the Interior and Coast-Interior Transition provenances. These tests are targeted at resolving questions of northward transfer, specifically of moving seed from the ICHmc1 to the ICHvc in the Transition, which is currently allowed but questioned by some local silviculturists. In addition, results of hemlock provenance tests will be used to estimate the risk of transfer for the purpose of enforcement issues under FRPA and to look for responses to climate change. There is also ongoing support research to assess the resistance of top orchard clones to mistletoe, given the Province's commitment to variable-retention silviculture systems. Lastly, a study was reported of the effects of allocating seedling resources to shoots versus roots on selecting for gain in volume at rotation at the nursery and sapling stage. Literature suggests that once roots are about 2 cm in diameter they adjust to wind stress on the crown. In the years before roots attain that size, tree breeding may result in some proneness to wind throw.

HIGH-ELEVATION HEMLOCK (SPU 24)

Tree improvement for high-elevation hemlock was envisioned to be a first-generation program in which testing of about 350 seed orchard parents would result in a genetic gain of about 15%. In this fiscal year, newly produced breeding values for 208 parent trees were added to 41 recently updated values. The last series of tests, which evaluated a further 96 parents, will be established later this spring. Based on the new breeding values produced this year, multiple copies of the best selections were grafted in anticipation of requests from seed orchards.

TRUE FIR FOREST GENETICS

PACIFIC SILVER FIR (SPU 09)

Twelve Pacific silver fir sites planted between 2002 and 2003 were maintained this year. In addition, age 5 measurements have been taken for the trials planted in 2002. It is anticipated that an analysis of the results will be presented at a conference in the coming summer. A further two test sites will be out-planted in the next fiscal year.

SUBALPINE FIR

Four nursery provenance trials for this species were established in 2002 and have all been measured in this fiscal year. To cover gene conservation concerns and long-term growth data, excess replacement stock was out-planted to two field sites, one on Vancouver Island and one in the Coast-Interior Transition near Whistler. In the coming year, two more of these tests will go out. One is to be near the tree line in the Transition, and another is to go on a cold, but lower-elevation Maritime site to allow investigations into cone stimulation.

Plate 3. Hemlock breeding arboreta. A pot-in-pot system, with greenhouse and outdoor holding areas, allows for manipulation of the time of flowering.

Plate 4. Root/shoot measurements for looking at the allocation of seedling resources.

4.4 Western Redcedar Breeding Program

John Russell, Craig Ferguson

There are 930 parents established in first-generation polycross tests for the maritime low SPU. Seven annual series of tests were planted on 46 sites over six SPUs. Breeding values for volume at rotation are currently available for series 1 through 3 based on seven-year heights (398 parents). Approximately 55 parents from the first four series have been selected for advanced generation and established into breeding orchards. Breeding for second generation is ongoing (Plate 5).

Thirty clonebank selections for high needle monoterpene concentration from the 930 parents in the polycross trials have been grafted, in addition to the sixty within-family selections from the Holt Creek, SVI family/population study. These selections are currently being bred using a combination of selfing and outcrossing, and resultant progeny will be screened for monoterpene concentration and deer resistance. Both backward and forward selections can then be incorporated into a deer resistant production population. A browse trial involving 45 clones from varying needle monoterpene levels was conducted at the USDA Olympia National Wildlife Centre field station this winter. Clones with higher needle monoterpenes survived longer despite very high pressure from a large number of captive bored deer (Plate 6).

Plate 5. Western redcedar greenhouse breeding orchard at Cowichan Lake Research Station.

Plate 6. Deer browsing at Olympia National Wildlife Centre Field Station.

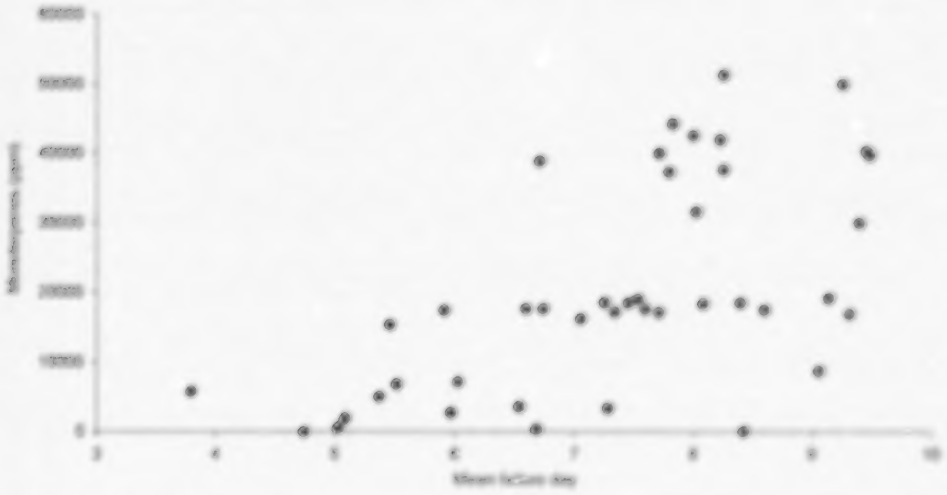


Figure 3. Relationship between western redcedar needle monoterpenes and browse pressure at Olympia.

4.5 Yellow-cedar Breeding Program

John Russell, Craig Ferguson

There are currently clonal values from approximately 5000 clones represented in three series of annual testing. Nine-year data from the first and second series of cloned progeny tests have shown that the top 1% of the mass selected clones results in 15% volume gain at 60 years. These new clonal selections have been repropagated for operational release. Clonal breeding values based on pedigree information were estimated using ASReml for advanced-generation selections. Deviations from a perfect correlation with clonal values estimated without pedigree information is indicative of significant non-additive genetic variation as well as pedigree. Maintenance continued this year in both field trials and breeding orchards, as well as monitoring of pollen performance and production for collection for advanced-generation breeding.

Various technical support projects were maintained and measured. These include clonal maturation, clonal competition, pollen viability, and deer resistance studies. Fifteen-year data has been collected from the first series of provenance trials, with the second series due to be measured next year.

Plate 7. Fifteen-year-old yellow-cedar provenance study at Cow River, 1000 m elevation.

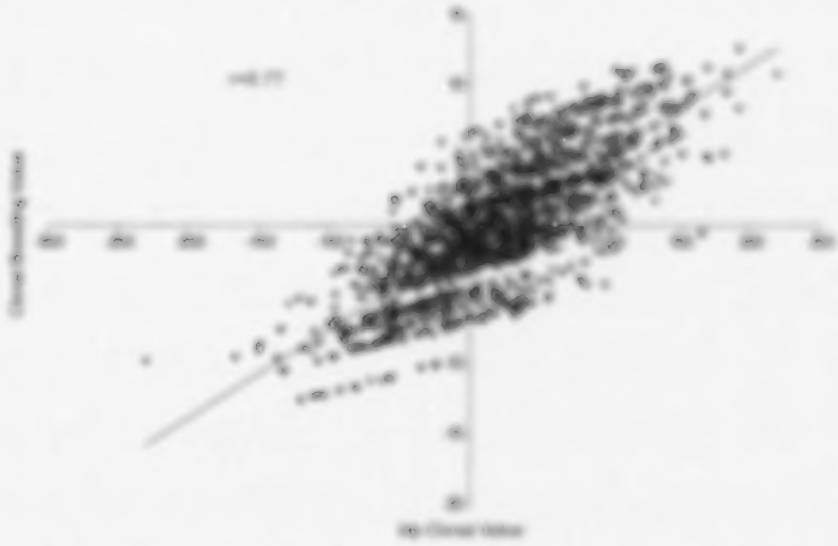


Figure 4. Relationship between best linear predicted clonal values estimated without pedigree information versus best linear unbiased predicted clonal breeding values with pedigree information.

4.6 Coastal White Pine

John King, Rich Hunt (CFS), Dave Penelton

Two phases of the F_1 breeding program have been established over the last few years (approximately 60 families over three sites in each phase). A final phase will be established this fall (2006) to complete this effort. Parents for this effort came from the CFS screening program and were designated as either Slow Canker Growth (SCG) or Difficult to Infect (DI). SCG or "slow rusting" trees occur more frequently than DI. Also included as parents were some of the best of the Tweedsmuir trees and some Idaho, Interior, and Dorena trees.

Although 2004 saw Rich Hunt's "official" retirement, luckily we have managed to retain Rich, part time at least, through an appointment within the CFS. Ongoing pathology support by the CFS is seen as vital, especially with the establishment of the F_1 generation. The university infrastructure that has developed with the entomology support (UBC – Genome Project – see Sitka spruce) has not developed with the blister rust-resistance program.

Recent publications on the white pine program include:

Hunt, R.S. 2004a. Blister-rust-resistant western white pine for British Columbia. Natural Resources Canada, Canadian Forestry Service Information Report BC-X-397.

Hunt, R.S. 2004b. Environmental and inoculum source effects on resistance of Idaho F_1 western white pine to British Columbia. Can. J. Plant Pathol. 26:351-357.

Hunt, R.S., L.D. Jensen, and A. K. Doomotthiullah. 2004. Confirmation of dominant gene resistance (D_1) in the U.S. white pine selections to white pine blister rust growing in British Columbia. Pp: 227-229 in Richard A. Sniezko,Saffya Samman, Scott E. Schlarbaum,and Howard B. Kriebel, eds. Breeding and genetic resources of five-needle pines: growth, adaptability and pest resistance: 2003 July 23-27; Medford, OR, USA. IUFRO Working Party 2.02.15. Proceedings IUFRO-P-32. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 259 p.

King J.N. and R. Hunt. 2006. Five-needle pines in British Columbia, Canada: Past, present and future. Pp. 12-19 in Richard A. Sniezko, Safiya Samman, Scott E. Schlarbaum and Howard B. Kriebel, eds. Breeding and genetic resources of five-needle pines: growth, adaptability and pest resistance. 2001 July 23-27; Medford, OR, USA. IUFRO Working Party 2.02.15. Proceedings RMRS-P-32. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 258 p.

King J.N. and A. Soolst. 2006. Genetic approaches to the management of blister rust in white pines. J. For. Evol. and Mgmt. (accepted).

4.7 Coastal Broadleaf Genetics Program

Chang Yi Xie

Interest in the commercial management of native broadleaf tree species in British Columbia is increasing rapidly. Questions related to seed transfer, selection of seed sources, potential genetic gain in growth and wood quality, seed (or cuttings) production and management, and gene conservation once had little relevance to broadleaf tree species in the province, but they have now become burning issues. At the present time, there are only a few applied gene resource management trials for broadleaves and very limited information on which to base gene resource management policy decisions.

The Broadleaf Species Committee of the Forest Genetics Council of BC decided to develop a Provincial Status Report on the following species:

- red alder (coast);
- big-leaf maple (coast);
- cottonwood (province-wide);
- paper and silver birch (interior and south coast);
- aspen (interior).

This report will:

- describe the geographic extent and potential commercial ranges;
- list available information on the inventories by logical administrative units;
- outline in broad terms the current harvest levels, plantings, and management;
- provide statistics on current commercial values;
- outline in broad terms the likely potential for expansion of harvest and commercial values;
- outline in broad terms the current policy impediments to managing broadleaves;
- describe the other advantages of managing broadleaves (i.e., biodiversity, visit-ish, increased stand ecological resiliency, etc.);
- outline existing genetic tests;
- recommend priorities for expanding broadleaf genetic testing and producing improved seed or vegetation.

It is proposed that the Provincial Status Report be completed by September 30, 2006.

There are two long-term provenance progeny test trials, one located at Shawnigan on Vancouver Island and another at Thunderbird near Terrace. Forty-two provenances, each with five families, are tested at each site. Ten-year test results suggest that two seed zones (breeding zones), one for the southern and another for the northern region, should be delineated to minimize maladaptation and maximize gain in seed deployment and tree breeding. The proper boundary between the two zones seems to be latitude 52° N. Significant latitudinal patterns of adaptive genetic variation in growth and survival suggest about 5% increase in mortality for each degree of northward and about 1.3 m^3 decrease in stem volume for each degree of southward transfer of seed sources. Two base populations have been constructed, one for each breeding zone. The base population for the northern zone consists of 800 trees of 48 families from 26 provenances north of 52° N at Thunderbird while the base population for the southern zone consists of 624 trees of 118 families from 16 provenances south of 54° N. Mostly forward selections have been made for the southern zone based on stem volume and other quality characters such as form and branch number and size. The average breeding value of the selections is about

15%. Selection for the northern zone will be conducted next year.

[illegible]

Two long-term provenance-clonal trials have been established with about 400 clones from 120 provenances. One site is located near Terrace and another at Red Rock near Prince George. A southern site at Harrison Mills will be established in 2007. Gene conservation, long-term genetic-trial study, and clonal selection are the main objectives of these tests.

[illegible]

Seeds from 43 provenances were collected in 2005. Thirty provenances are located in BC, four in Washington, four in Oregon, and five in California. Ten trees were sampled in each provenance and seeds from each tree are being bagged separately. Four provenance-progeny test trials are going to be established in 2007. Ideally two on Vancouver Island and two on the coastal mainland.

4.3 Interior Douglas-fir Tree Breeding

[illegible]

Grafting: In the Nelson (R1), all controlled crosses were completed and 120 pollen mix were collected, processed, and stored for future crossing. Controlled crossing in the Nelson (R1) is now about 70% complete.

Progeny testing: Four 18-year-old sites in the Kootenay Basins test series were maintained and two of the sites were measured. The 18-year-old range-wide provenance test at Trinity Valley was maintained and measured. Data analysis of both sites are ongoing.

Seed/cone assistance screening: The joint BC Ministry of Forests and Range/Forestry Canada pilot project to screen Interior Douglas-fir families for resistance to seed/cone and shoots flies/cone in the 2006 cone crop was collected with assistance. 1,000 (66.6%) days, mainly mid-May, ranged from 41 to 100%. Interestingly, there was a weak but significant correlation ($r = .21$) between flowing receptivity and abundance of the second flies. Data analysis is ongoing.

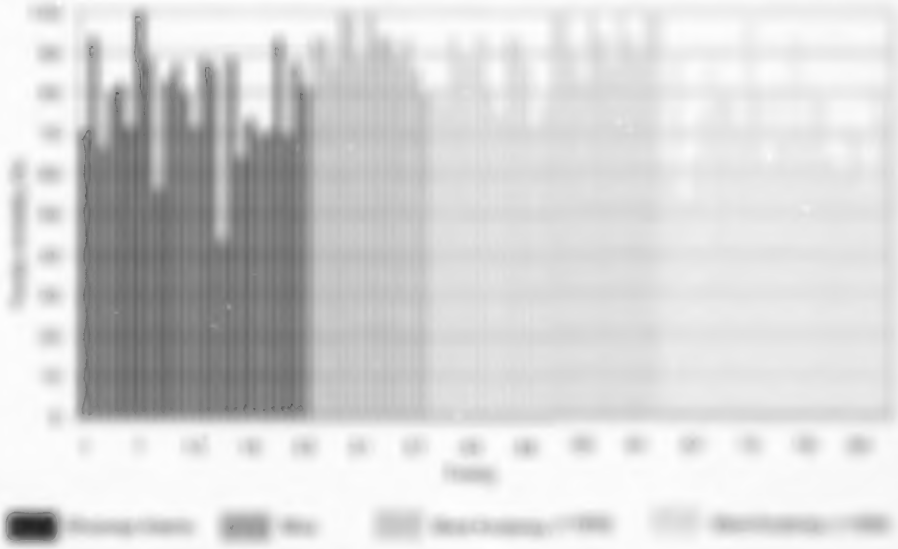


Figure 2. Proportion of trees infected by seed/cone-galling chalcid (Douglas-fir seed/cone) and shoots.

[redacted]

[redacted]

[redacted]

The Interior spruce tree improvement program is the oldest program in the BC Interior. The Kalum Provenance Project in the mid-1980s and the Prince George Provenance Project in the early 1990s established progeny testing plots in the Prince George, Vanderhoof, and Fort St. John areas. The program's objective is to increase the genetic gain in the Interior Spruce (SX) resource by selecting trees with superior growth, form, and resistance to common pests and diseases. Through successive selections for genetic improvement, the program has progressed to the second generation of selections. Seed orchards have been established to produce genetically improved seed for reforestation. Seed orchards are managed to maximize seed production and minimize pollen contamination from nearby stands. Seed orchard crops are collected, processed, and stored. Seedlings are grown in nurseries and planted on cutblocks throughout the province.

Tree improvement programs are long-term projects. Results from the first-generation progeny tests are now available, and second-generation crosses are underway. Breeding populations are maintained to ensure genetic diversity is preserved for future generations. Gene conservation activities include collecting seed from wild stands to represent the genetic variation in natural populations. Research trials are established to test the performance of improved seedlings in different environments.

[redacted]

[redacted]

[redacted]

[redacted]

The [redacted] system must compete not only [redacted] but also [redacted]. The [redacted] family has [redacted] and through successful application [redacted] marketing ability.

The other components of the program are [redacted] effective [redacted] and [redacted] and successful [redacted]. It also [redacted] and [redacted] and [redacted] [redacted] [redacted]

[redacted]

[redacted]

[redacted]

Plate 14. Mark Ukrainetz at a PG Orchard Clone (left) and Wild Seedlot (right) demonstration at the Skeetkin seed orchard site.

Plate 15. Mark Ukrainetz and a Yellow Cypress Seed crown from operation demonstration at the Skeetkin seed orchard site. Cut by crew found in the mid 1990s.

Plates 17 and 18. "Karelian" Silver Birch from Finland, 8 years at the Skeetkin Seed Orchard Site. Karelian produces curly grained wood used in specialty manufacturing in Finland; bowls, knife handles, gun stocks, etc.

Birches received a lot of attention in 2006. We re-measured our two birch genecology trials (38 seed source at 11 yrs and 47 seed source at 8 years). Also measured was our 9-year-old, 105 wind pollinated family trial at the Skeetkin site. The genecology trials are sufficiently mature to allow our first consideration of birch seed transfer guideline development. Analysis of the family trial data will allow selection of a small elite subset of test trees that will be both grafted and rooted in spring/summer 2007. These clones will be the parents of our first paper birch seed orchard in BC.

Plate 19. Future forest overstory. Left: Measuring a 9 year old wind pollinated family trial of paper birch at the Skimikin Seed Orchard Site. Our first Paper birch seed orchard will be grafted in 2007 from the finest trees in the trial.

Plate 20. Measuring the 47 seed source paper birch provenance trial at the Skimikin seed orchard site at 6 years in the field.

Estimates of hybrid cottonwood standing volumes on the wastewater-irrigated Vernon commonage were made so as to plan for the harvesting and sale of approximately 5 hectares of cottonwood logs in 2007. Average volume per hectare at 19 years is approximately 450 m^3. A non-irrigated hybrid cottonwood trial in the Kootenay River valley near Creston had one clone with estimated stem volumes of approximately 350 m^3 per hectare after 10 field seasons.

Plate 21. Cottonwood stands, Vernon Commonage.

Plates 22 and 23. John Murphy, Vicky Berger and Nicholas Ukrainetz selecting gall free seed orchard parent trees in 2006 infected progeny test plantation near McKenzie, Sept. 2006.

Plate 24. Vicky Berger in a hybrid poplar clonal trial planted 1997 in the Kootenay River Valley near Creston, Sept. 2006.

5.0 Operational Tree Improvement: The Ninth Year in Review

Roger Painter

With the end of our ninth year, a very large spectre looms on the horizon for the forest industry and tree improvement in particular. Our forests are being inundated by what looks like the most pandemic pest attack in our province's history. Mountain Pine beetle has attacked our forests in unprecedented numbers and threatens as much as 25% of the province's standing merchantable timber. Little did we know when we began setting up SelectSeed Ltd. that we would be setting ourselves up to address this natural disaster. It would be too much to expect that we planned enough seed supply to meet any needs that the province will require for dealing with Mountain Pine beetle, but our timing will enable us to provide key amounts of seed for restocking higher sites and perhaps even enough to look at establishing greater amounts of seed to deal with what could be a 35 to 45-year problem. Possible solutions to the long-term issue of regenerating future forests relate to having the infrastructure to ramp up and meet the challenge. The Tree Improvement Program has this ability due to key investments in breeding and testing, OTIP, seed pest management, and SelectSeed. Over the years the Operational Tree Improvement Sub-program (OTIP) has provided the focus for investing in our orchards for the purposes of increasing genetic gain as well as seed yields. Seed requests in 2005-6 have almost reached 50% of provincial reforestation needs, and our genetic gain is close to meeting the overall target set for 2007 by the Forest Genetics Council back in 1997. This sub-program represents the strategic device that we have employed to invest in, and bring existing orchards up to their potential. This, coupled with the development of replacement stock from the breeding programs, has raised the genetic worth of orchards to more acceptable levels. At the same time this program relies on a system of performance management to monitor progress and set reasonable targets for project success. Orchardists and researchers have responded to these approaches and in many instances have over achieved.

Although 2005-6 was a lighter than normal year for most species crops, considerable work continues in stock replacement and studies on seed supply issues. There continue to be insect-related issues that reduce seed yields. This year more emphasis has been focused on Seed Pest Management along with presenting a stronger mandate for research in that field and further development of the Seed Pest Management Technical Advisory Committee and its associated sub-program. Future research and development projects that used to come through OTIP now go to this sub-program. This continues to show the depth of planning, and leadership in the overall program that allows us to concentrate our efforts despite limitations in funding. The Forest Investment Account continues to show strong support for our program and to keep funding constant at current levels. Available seed supplies from seed orchard seed continue to increase, and the genetic quality of seed crops continues to improve. The long-term result means that our province will enjoy a future supply of excellent wood products and a healthy resource as a result of the foresight of investing now. Issues and challenges like Mountain Pine Beetle will be addressed and acted upon.

In 2005-6, the two technical review committees reviewed a total of 79 requests for funding in OTIP. The total amount of proposals received was approximately $781,000. The Coastal and Interior technical committees recommended approving $643,125. The breakdown of investment by region for all of OTIP is as follows:

Interior projects	47	$463,939
Coastal projects	29	$179,186
Overall Total	**76**	**$643,125**

Table 2. Number of projects and funding by region.

Various species committees exist to support the Forest Genetics Council, and they review and develop annual projects and priorities. Both the Tree Breeding and the Operational Tree Improvement Program receive their direction from these reviews. Similarly the Extension and Gene Conservation TACs have developed their own priority review procedures. Tree Breeding is a Ministry of Forests and Range responsibility and is not part of the OTIP "Call for Proposals" process. Priorities for the Tree Breeding sub-program are still developed through the species sub-committees, but decisions on projects to be undertaken are reached through co-ordination with the Tree Improvement and Research Branches of the Ministry of Forests and

Range and the FGC Program Manager. Considerable investment is needed in this sub-program, and it will continue to receive strong levels of support to ensure the development of new production stock for future orchards. New orchards focus on producing seed for Seed Planning zones where production capacity is low and/or where priorities for genetic quality seed are high. New orchards also help produce stock to replace older less advanced stock in existing orchards. Work in Tree Breeding has already provided much of the genetic material to establish a number of new orchards recently and to enhance existing ones. The development of a long-term investment program through SelectSeed Ltd. will eventually produce over 40,000 grafts to establish new orchards.

Technical support within the OTIP sub-program is an integral part of tree improvement in general and provides an excellent avenue for operational problem-solving. The Lodgepole Pine seed-set issue has been an excellent example of a focussed investigation to solve a serious problem that affects tree improvement. This program area will also work on orchard issues related to Mountain Pine beetle. Listed below is a project breakdown by areas of investment for 2005-6:

Tree Breeding	28
Gene Conservation	8
Operational Production	61
Technical Support	14
Seed Pest Management	5
Extension and Communication	6
Seed Planning and Information Tools	4

Table 3. Number of project/area of investment

The tree improvement industry represents a broad spectrum of partners that includes forest companies, the provincial government, the Canadian Forest Service, universities, private bio-technical companies, and individuals. In 2005/2006 the Tree Improvement Program involved 37 separate contributors from all parts of our industry. The Forest Genetics Council continues to provide sound leadership and management through its technical committees and through the use of a strong business management approach for setting priorities and goals for investment.

5.1 Orchard Projects

5.1.1 Saanich Forestry Centre

Annette Van Niejenhuis

The Saanich Forestry Centre, wholly owned and operated by Western Forest Products Inc., manages production tree seed orchards for low-elevation Douglas-fir, low-elevation western redcedar, low- and high-elevation western hemlock, and low-elevation Sitka spruce seed planning units together with hedge orchards for the yellow cypress seed planning unit, all in the Maritime Zone. As a co-operator in the Forest Genetics Council programs aimed at delivering quality seed in quantity to the coastal forest regeneration programs, WFP employs incremental management techniques using OTIP-awarded funds.

COASTAL DOUGLAS-FIR CROP AND ORCHARD ENHANCEMENT

Scion has been collected, and grafting of 18 new clones, together with additional copies of previously selected clones, will raise the average genetic worth of future crops produced in the orchard from 12 to 18. More than 200 ramets will result from this grafting project.
The 2005 Douglas-fir crop delivered 23 hl of cones whose seed has an average GW of 11%. Insect damage was again significant.

WESTERN REDCEDAR ORCHARD AND CROP ENHANCEMENT

Supplemental mass pollination aided in the delivery of a larger crop from orchard 189 in 2005. More than 4 kg of seed with a genetic worth of 5 was produced. Midge infestation was light, which further improved the seed recoveries.

Giberellic acid applications, as per our approved request for use under research applications, increased the flowering of treated ramets in orchard 189. Supplemental mass pollination of these crop trees is underway.

LOW-ELEVATION WESTERN HEMLOCK CROP ENHANCEMENT

Supplemental mass pollination was applied to the western hemlock crop, with a focus on clones with a high propensity to self. The genetic worth of this crop, totalling 2.24 hl, is 14. High-gain seed is needed in this SPU; little seed of genetic worth of 9 or greater is banked.

HIGH-ELEVATION WESTERN HEMLOCK ORCHARD AND FUTURE CROP ENHANCEMENT

Wet weather late in 2005 resulted in deferring the planting of replacement ramets. Plans are in place to plant the stock before the end of the fourth quarter. With the addition of more than 300 high-gain ramets, the average breeding value of orchard 187 will exceed 7% gain at rotation.

SITKA SPRUCE ORCHARD AND CROP ENHANCEMENT

Increased seed production in the weevil-resistant Sitka spruce orchard was demonstrated in the 2005 crop, which produced a harvest of almost 1 kg of seed. Supplemental mass pollination appears effective in delivering projected seed quantities from this young orchard.

Ramet replacement will continue with the addition of 17 ramets. These are additional copies of clones previously grafted without success, or replacements for mortalities. Initial progeny trials have been established. Upon receipt of results from these trials, roguing decisions to optimize weevil resistance while maximizing growth will be implemented.

YELLOW CYPRESS PRODUCTION HEDGES ENHANCEMENT

Enhanced management of the yellow cypress hedges at Saanich Forestry Centre included mid-season pruning to promote lateral growth. As a result of this effort, cuttings for more than 300 K plantables with an average genetic worth of 21% volume gain at rotation were delivered to the nursery for stock production. Wet weather has deferred planting until late winter.

YELLOW CYPRESS OPTIMUM ROOTING STRATEGY STUDY

A study of the optimum rooting strategy for yellow cypress was initiated. Cuttings from the TimberWest and Western Forest Products hedges were harvested and set at Sylvan Vale and Arbutus Grove nurseries on four dates. December set dates yielded significantly higher numbers of rooted cuttings than other set dates.

YELLOW CYPRESS CLONAL ROOTABILITY STUDY

A clonal rootability study of high-gain yellow cypress clones was established to permit selection of good rooters in the production hedges. Nine MoF&R clones from TimberWest and Western Forest Products hedges and 22 WFP clones from Western Forest Products hedges were set clonally in November of 2004 at Arbutus Grove and Sylvanvale nurseries. Results from the first year of the trial show recovery averages ranging from 15% to 81% among the clones tested, with an overall average of 43%. Testing is incomplete on all clones; the project will be continued to identify poor-rooting clones for roguing from production hedges. A clonal rooting score will be accepted for a clone when it has been included in three tests that have occurred in at least two production years and at least two nurseries. Our objective is to provide stock with an average rootability of 70%, which will require nursery over-sows of 43% to meet orders.

Plate 25. MoF&R Douglas-fir breeder Michael Stoehr at a Jordan River Operation Fdc test site next to an elite tree.

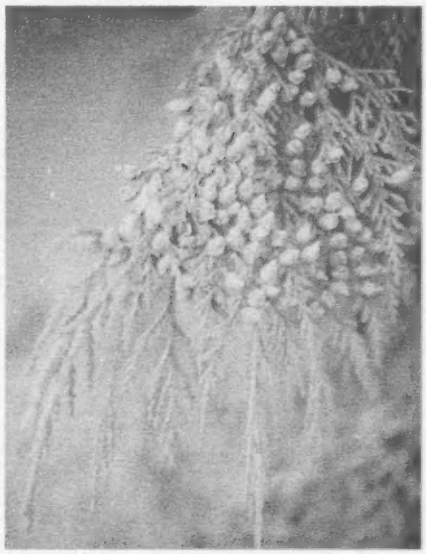


Plate 26. Western redcedar cones, including some damaged cones, as seen in early July.

Plate 27. Sitka spruce flowers are isolated in bags for Dr. John King's breeding program.

Plate 28. The SFC Douglas-fir crop yields high-gain seed to the operational reforestation programs.

Plate 29. Georgina Dampier grafts selected high-elevation western hemlock scion to rootstock for the improvement of SFC orchard 187.

Plate 30. Developing western hemlock cones in orchard 170 yield seed of 14% volume gain at rotation.

Plate 31. Pollen cones on western hemlock display microsporophyll separation just prior to pollen shed.

Plate 32. To induce cone production in the following year, Paul Bertorelli applies gibberellic acid to the foliage of western redcedar.

Plate 33. These developing Sitka spruce cones produced seed for weevil-resistant Sitka spruce reforestation programs.

5.1.2 Sechelt Seed Orchard

Patti Brown

CANFOR

DOUGLAS-FIR

Four hundred and fifty ramets from orchard 177 were assessed for health/graft union problems and 370 healthy ramets were injected with $GA_{4/7}$ in May 2005 to produce a crop in 2006.

The objective of project 3101 was to maximize the seed yield of the 2005 crop to help alleviate the seed shortage in SPU 31. Insecticides were applied to 80 ramets in orchard 116, 10 per treatment, to test the potential of new, more environmentally friendly insecticides/applications on the treatment of Douglas-fir seed and cone insects (*Dioryctria*, *Contarinia*, *Megastigmus*, etc.). Results are contained in a report being compiled for OTIP Pest Management – Systemic Insectide Tests.

WESTERN REDCEDAR

This project continues with the process of producing and maintaining redcedar ramets from all test series by adding Series 4, 5 and 6 to the holding beds in Sechelt.

Grafts potted up and maintained from series 4 through 6 breeding tests numbered 2,600.

A hundred and fifteen ramets with a GW of 9 or better from series 1 and 3 were added to orchard 186 to replace rogued selections (based on series 2, age 7 test results), and another 500 ramets were rogued from the holding beds based on these test results.

Throughout the period, regular fertilization, watering, and pruning promoted the health and vigour of the top 10% of selections in the holding beds from series 1-3 plus all selections from series 4-6 .

All ramets in orchard 186 were treated with dimethoate in April 2005 and monitored and treated with Sevin throughout the summer to reduce damage from *Mayetiola* and *Lygus*. Seed yield was approximately 1kg/hl with a potential for extracting 1 million seedlings with a GW of 8%.

WESTERN WHITE PINE

MGR pollen was collected from the MGR identified trees in the Robert's Creek test site and reapplied to all female cones produced in 2005 in orchard 174.

One hundred fifty grafts were made from the newest CFS slow canker parent tree selections.

The 600 cone-producing ramets were monitored and spot treated for *Leptoglossus* control on a regular basis throughout the seed production season. Undeveloped cones attacked by *Conopthorus* were collected and burned before the season for collecting cones for future control purposes.

YELLOW-CEDAR

SPU 1101 continues with the goal of producing 300,000 stecklings with a GW of >12% annually for our coastal operations. To achieve this, donors are grown and cultured at Cairnpark Nursery. Five hundred new yellow-cedar donor plants with an average GW of 20 were developed using the top Ministry of Forests and Range series 1 (age 9) selections and series 2 (age 5) selections as well as new material from the top selections at Western Forest Products.

Plate 34. The Cw project (which ports up potential Cw selections).

5.1.3 TimberWest Mt. Newton Seed Orchard

Tim Crowder

TimberWest

DOUGLAS-FIR

SPU 0106 covers activities in four Fdc M Low orchards: 134, 154, 183, and 197. Orchards 134 and 154 are mature orchards that are rogued and upgraded as new ramets are available. Orchard 183 is a younger orchard that is in full production, while orchard 197 is in the establishment phase.

SMP was carried out on early- and late-flowering clones in orchards 134, 154, and 183, as well as on the few ramets in 197 that flowered. Cones were monitored for *Contarinia* midge during the pollination season, and because infestation levels were high, all orchards except 197 were treated with dimethoate using an air-blast sprayer. Over 850 ramets were induced by stem injection of $GA_{4/7}$ to produce a crop in 2006. All four orchards were fertilized by injection through the irrigation system, and newly planted trees were top-dressed with a granular fertilizer and hand-watered as necessary.

In our grafting program we use large (PSB 1015) containerized root stock, which allows us to produce ramets that are ready for transplanting into the orchard within one year. This year we planted over 700 vigorous young ramets into vacant orchard positions. Another 700 smaller ramets were maintained in holding beds.

In the fourth quarter, 1000 new grafts of high BV clones were made for future upgrading of the Douglas-fir orchards.

WESTERN HEMLOCK

SPU 0205 covers activities in two Cw R Low orchards: 140 and 152. These two orchards are similar in composition and are typically induced in alternating years to provide a steady seed supply. In 2005, the cone crop was produced in orchard 152, while orchard 140 was induced for a crop in 2006.

Grafted ramets from test series three were maintained in a holding bed, while those from test series four through six were maintained in a potted holding area. The grafts were staked, fertilized, pruned, and labeled as required.

WESTERN HEMLOCK

SPU 0310 covers activities in Hw R Low orchard 182. This orchard has been producing small crops since 2002 but has not yet reached full production capacity. Because of the small size of the ramets, SMP was used again in 2005 to supplement the insufficient pollen cloud.

Approximately one-third of the orchard was induced by stem injection of $GA_{4/7}$ to produce a crop in 2006.

All ramets were fertilized by injection through the irrigation system, and were pruned to increase the surface area for cone production.

WESTERN WHITE PINE

SPU 0908 covers activities in Pw orchard 403. In 2005, rust-resistant WGR pollen was collected from the Ladysmith test site and was applied to most of the developing cones for the 2006 seed crop. The 2005 crop was monitored for *Leptoglossus* and was spot treated frequently for control of this pest. In addition, 65 new ramets were planted to replace mortality and increase rust resistance.

YELLOW CEDAR

SPU 1109 covers activities in our yellow-cedar hedge orchard. Over 3000 production ramets with an average BV of 12% were cultured and maintained, as well as a holding area for 1800 ramets of 120 clones in the RoF&R testing program. The production capacity of the hedge orchard is 350,000.

Photo 35. Douglas-fir cone harvest with pole-pruner at MK Nanaimo Seed Orchard.

3.1.4 Bowman Seed Orchards

Dan Rudolph

[abstract: aim, locations, and treatments; seed output and quality; the six-year induction schedule; and the seed orchards]

This project is a multi-year effort and is being conducted in three second-generation seed orchards, 1st6, 162 and 168 (a store-orchard containing the same clones as 162), at the Ministry of Forests and Range site at Bowen. There were two main objectives:

1. to upgrade the genetic composition of the orchards by rogueing the lowest-ranked clones and replacing them with higher-ranked parents;
2. to enhance the seed yield and genetic worth of the seedlots produced by:
   - employing cone induction techniques for all suitable candidates in each orchard;
   - utilizing controlled pollination techniques in all orchards;
   - employing orchard management techniques to optimize growing stock vigour and crop health.

RESULTS

Upgrading

While it was originally intended to upgrade these orchards with newly propagated stock, this part of the upgrading program has been cancelled and the stock originally intended for Bowen has been re-assigned to the new orchard 189 at the ministry's Saanich site. It has been possible, however, to obtain a measure of upgrading this year in orchard 1st6 by rogueing 215 ramets of 12 families with BVs of less than 5 and by transplanting into orchard 1st6 ramets of 52 clones from orchard 168. These clones have BVs ranging from 16 to 28.

Enhancing seed yield and genetic worth

Controlled crossing: 71 ramets from the top-ranked parents in each orchard were identified, and isolation bags were put on 1101 branches of these ramets. However, because 137 bags were lost due to a late spring storm, the total number of bags remaining was 964. Controlled crosses using pollen mixes with high genetic worth were made. Pollination bags were replaced with insect bags after orchard receptivity had passed.

Induction: Suitable candidates for induction were identified in each orchard. Criteria used to establish a candidate list included: negligible current year's crop, no crop from last year, no induction treatment last year, sufficient vigour, and an adequate number of cone-bearing sites. Induction treatments consisted of double overlapping girdles. Irrigation was withheld until mid-July in order to increase drought stress on the trees.

Orchard management: All orchard trees were maintained through appropriate cultural practices.

Insect management and control: Surveys were conducted for *Contorinia* (hagworm) and *Leptoglossus* (leaf-footed bug) and a trapping program for *Dioryctria* (coneworm) was initiated.

OUTPUT AND DISCUSSION

Upgrading

The removal of the lower-ranked clones in orchard 1st6 and their replacement with the higher-ranked clones from orchard 168 has raised the mean, weighted orchard BV from about 8% to 13.45%.

Enhancing seed yield and genetic worth

Controlled crossing: Seedlot 89998 was produced from the controlled crosses done in the spring. Seed yield was 0.675 kg of seed with a genetic worth of 16.2.

Induction: A total of 214 trees were induced — 81 from orchard 1st6, 108 from orchard 162 and 24 from orchard 168. But surveys to rate efficacy of the treatments will be done in late March.

Orchard management: Foliar nutrient samples were taken, fertilizer was applied for both growing stock and crop maintenance, irrigation was applied when necessary, trees were basal-pruned, top-pruned, and inter-nodal-pruned, and identity tags were upgraded prior to cone collection.

Insect monitoring and control: Because *Contorinia* levels were within the acceptable threshold level, no control measures were necessary. Because *Leptoglossus* levels were also low, no control measures were undertaken.

The diagnostic mapping program was conducted at four other orchard sites (orchids Browse Cleanrich, TimberMaid, AFF, and ATF blocks). Site totals ranged from a low of 46 at Cleanrich to a high of 103 at TimberMaid. Mean was 287. The map total at Browse was 204. No control measures were undertaken because chemical control, the most practicable option, is not permitted at this site. An estimate of the losses incurred from this pest can be inferred from the yield figures for the main orchard crop. Yields this year averaged 18.6kg/tree, down 32-40% from the average of 2002 (kg – 200 kg/tree).

[redacted]

Six DTIF projects were approved under the vocational production sub-program for 2005/2006 at Nakenaka Seed Orchards. The funding allowed for a significant enhancement of the effectiveness of our orchards in delivering improved seed. Activities included:

- improving orchard composition through grafting higher breeding value seeds, maintaining recently grafted high-value seeds destined for orchards, planting materials for future grafting, transplanting the older higher value seeds to the orchards and ongoing lower value seeds from the orchards;
- improving orchard seed quantity and quality through pollen management, including collection of high-breeding-value pollen from clone bank and the application of supplementary flash fertilization;
- improving orchard productivity through pest management and other management activities.

Pest management activities funded included:

- use of baited in-loop sprays to control gall-fly adelgids;
- removal of adelgid-infected spruce basket to reduce insect populations;
- removal of pine pitch moths damaging orchard trap plants;
- baiting for control of rodents feeding on trap nuts;
- perimeter planting of crops in orchards with non-collectible crops to reduce pest populations;
- increase of applications to control aphid adelgids;
- sprays to control Blegvirbi fungus;
- sprays to control cankerworm;
- sprays to control pollen bugs and diseases in indigenous pine orchards.

Other funded management activities to boost productivity and gain included timely analysis to determine the optimum stages of orchard trees and correct management of orchard trees.

The DTIF funding has instrumental in increasing both the quantity and quality of seed produced. At Nakenaka in 2005 we produced approximately 17 kg of seeds/1 unit. Indigenous pine cut seasons yields one seed equivalent to one to millions seedlings, with an average GR of 1:40. Nakenaka seed is being used over large areas of the interior of the province.

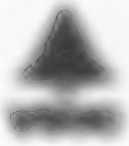
Project	Species	SPU	Orchard	Flagging	Quality Mark	Maintenance	Protection	Completion
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 4: Orchard composition activities by project

Project	Objective	PI(s)	Amount	Status / Outcome (Active, etc.)	Year Initiated
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total					[illegible]

Table 2. Select [illegible] projects funded [illegible]

[illegible] Harrison Seed Orchard Expansion (HSOE)



Fundraising

[illegible] projects were funded through the Appalachian Hay Improvement Program at Berea Seed Orchard. These projects contributed to the ongoing process of improving the quality and quantity of seed produced for reforestation in the Interior of Northern Grandeur.

Harvesting, Processing, and Packaging Quality

Collecting, processing, and packaging quality with a high breeding value is costly and labor-acquiring. Access to fundamentals is ensuring high seed production with quality. The use of a helicopter during pollination amplifies the pollen cloud and increases its availability for uptake.

Seed Traits

All three reduce N contents, as with a [illegible] trial of 50 untapped pine seeds, was determined to [illegible] the [illegible]. A Douglas-fir contains the most positive effects on seed production. To gain more experience and knowledge of the effects of [illegible], an untapped pine, a small trial was initiated to [illegible] appropriate mixing and dosage of applications. Results and N as opposed to with spring [illegible].

Operational Security

To ensure the continued health and high vigor of seeds, as well as the production of nutrient-type, and

Fig. 8. Spring N [illegible] of Douglas-fir.

Fig. 9. Cone [illegible] Douglas-fir.

[redacted]

[redacted]

[redacted]

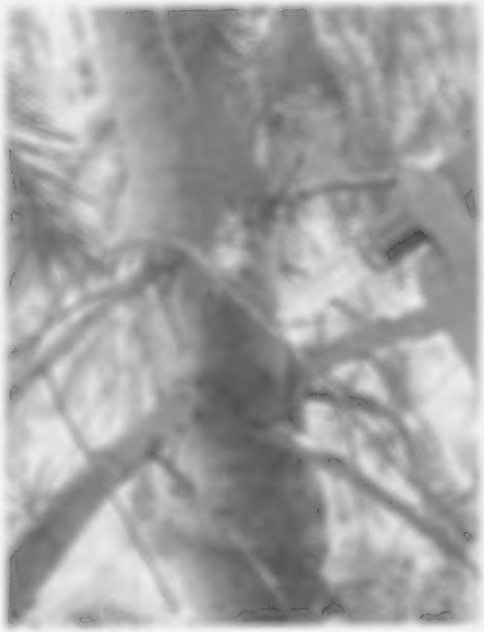


Plate 39. Flower induction – GA stem injection on orchard PG 321.

Plate 40. Collecting pollen using backpack vacuum, on orchard PG 311.

number of locations within the orchard, and they were monitored daily until the pollen flight was completed. Pollen shed and female receptivity were monitored throughout the pollination period (phenological survey), indicating the timing for SMP applications. The survey information also allowed us to identify and pollinate early- and late-flowering clones.

Pollen was applied three times in April (SMP) with stored pollen. Pollen for future use was collected by a PRT crew at the Kalamalka Forestry Centre. Thanks to Barry Jaquish and Valerie Ashley for providing access to the clone banks for pollen collection and assisting the PRT crew. Approximately 1.34 litres of pollen was collected, processed, and put into freezer storage.

Throughout the season, the F45 orchard was monitored for insect, rodent, and disease problems. This ensured that measures were taken to protect cone health and developing cones. Insecticide sprays were applied to protect the crop from *Dioryctria* (fir coneworm). Damage to the cones by *Dioryctria* was substantially reduced in 2005 due to vigilant monitoring and correct timing of insecticide sprays. In 2003 and 2004, more than 60% of the cones were affected by *Dioryctria* feeding. Less than 10% of the crop was affected in 2005. Poison baits were set out to control rodents feeding on tree roots.

Flower induction using gibberellic acid was done on 135 trees by stem injection. This is expected to stimulate flower (cone) production in 2006.

A small amount of crown pruning was done in orchard 521 to cut back long leaders and control lateral branches growing into the roadways.

All projects were completed as planned in 2005. In the PG Thompson Okanagan Low, 16.45 kg of seed was collected with the potential to produce 3.3 million seedlings. In the PG Nelson Low, 8.27 kg of seed was collected with the potential to produce 1.65 million seedlings. This was the first crop for orchard 337, which contributed .413 kg of seed to the PG NE low. The F45 Nelson Low orchard produced 3.35 kg of seed with the potential to produce 330,570 seedlings.

The activities conducted in 2005 with the assistance of OTIP funding ultimately move us towards our goal of increasing the amount and quality of A-class seed for the PG NE low, PG TO low, and F45 NE low seed planning units.

5.1.8 Eagle Rock Seed Orchard, Tolko Industries

Greg Pieper

PROJECT 1601 SPU 16, LODGEPOLE PINE T.O. HIGH

- Pollen was collected and stored for future use in orchard 339. Pollen was dried down to 7% moisture content and stored at -25 C.
- A helicopter was used three times to spread pollen throughout this orchard for increased seed set. This year we had an average of 8.5 seed per cone, the best seed fill to date.
- *Leptoglossus* was controlled using four sprays of Sevin XLR. Although *Leptoglossus* densities were lower this year, they still posed a threat.
- A fungicide was used in an attempt to control needlecast, with marginal success. Trees were sprayed with a mist blower with little effect. A more intensive spray program is planned for this orchard in 2006.
- Western gall rust was controlled through hand clipping of all infected stems. We anticipate that several sprays to control needlecast with a fungicide may also help control the spread of gall rust this coming year.
- Sequoia pitch moth continues to be an increasing problem in this orchard. Two passes to remove the larvae by hand were conducted, with adequate results.
- "Whole tree insect exclusion bags" were made onsite to see if total exclusion of *Leptoglossus* would result in increased seed numbers. Because lepto counts were not as high as in the past and intensive spraying was used to ensure that populations remained low, results were mixed. We intend to put the bags back on again in 2006.
- Foliar and soil analyses were done in October.

PROJECT 2601 SPU 26, ENGELMANN SPRUCE T.O. HIGH AND LOW

- In preparation for a future second-generation Thompson Okanagan Spruce Orchard, pollen is being collected and stored. Controlled crossings are being done as females are available. To date, 18 of the 160 crossings are complete. This year we were able to complete eight of these.
- Because adelgid surveys showed that densities were low, spraying was not required.
- GA cone induction was done on 343 ramets that fell into the high-elevation, high-breeding-value clones. A crop is expected in 2006.
- Foliar and soil analyses were done in this orchard in October.

5.1.9 Prince George Tree Improvement Station

Rita Wagner

SPU 1203, 1802, 1702

Activities are aimed at increasing the quantity and quality of lodgepole pine seed from orchard 220 (Prince George low planning zone), orchard 223 (Central Plateau low planning zone), and orchard 228 (Bulkley Valley low planning zone).

Three Operational Tree Improvement projects (SPU 1203, 1802 and 1702) were conducted at the Prince George Tree Improvement Station in 2005-2006. High-gain clones located in clonebanks and older orchards produced 15.5 L of pollen for pollination of early and late flowering clones in orchards 220, 223 and 228. Phenology surveys were completed to identify early/late flowering clones. Crop surveys were carried out, and our many non-serotinous clones were monitored frequently to avoid any loss of seed.

Foliar samples were taken, and analyses of nutrient status were completed in the fall. Trees in all orchards were surveyed for western gall rust, *Lophodermella* needle cast and root collar weevil. Mountain pine beetle surveys were done frequently during the extended beetle flights.

Due to the extremely heavy mountain pine beetle attacks in the surrounding area, entomologists advised against stressing trees, either through GA or topping/branch pruning. Previous experience in one of our orchards has shown that beetles are attracted to the pitch from pruning wounds on trees that are thin-barked and less than 20 years old.

Flower production on trees that received $GA_{4/7}$ in 2004 was assessed in spring 2005. Ramets that received GA showed a measurable increase in flower production: most treated trees showed up to 1/3 or more flower production than the non-treated trees in a clone.

Extra fertilizer was applied to keep trees as vigorous

as possible. Due to the rather wet spring to fall season, irrigation was not required.

The fall 2005 cone harvest from the three orchards yielded a bumper crop of 45.131 kg of seed and 7.8 million potential seedlings with a genetic worth of 6%.

Plate 41. Aerial photo of PGTIS. Foreground: Willow-Bowron 220 orchard, background: Bulkley 228 orchard and office/compound area beyond.

Plate 42. Cone picking with a girette in the Willow-Bowron 220 orchard with the Bulkley 228 orchard in the background and the office/compound area in the distance.

Plate 43. Aerial photo of PGTIS. Office to left; foreground Bulkley 228 orchard; and towards back right, Pine Provenance Plantation.

Plate 44. Bottom branch pruning/chipping.

Plate 45. Topping in the Willow-Bowron 220.

5.1.10 Skimikin Seed Orchards

Keith Cox

PROJECTS 404, 411, 501, 1503, 3502, 4002, AND 4201

Work was funded in the research plantations and eight of the seed orchards at Skimikin in 2005.

The West Kootenay (Nelson mid and high) spruce orchards had 439 replacement grafts made in the spring, and 387 surviving grafts were planted in the holding area in September. In orchards 301 and 302, 500 trees and 617 trees respectively were injected with GA and drought stressed to the end of June to produce a crop for 2006. The orchards were surveyed for insects and disease, rust brooms (*Chrysomyxa arctostaphyli*) were removed, and rodents were baited. Based on ten-year breeding values, 894 trees were removed from orchard 301 and 639 trees from orchard 302, and their average breeding values increased to seven and six. The trees were hauled to the nearby Salmon River for stream-bank restoration.

The white pine orchard (609) was monitored extensively because of the mountain pine beetle, the conifer seed bug, and the pine cone moth. The monitoring resulted in 33 surveys during the season. A total of 105 litres of pollen buds were collected for supplemental pollination in orchard 335 at Bailey Road.

In the three spruce orchards for the Bulkley Valley Low, the crop was sprayed for spruce cone maggots and spruce cone rust. In May, 869 trees in orchard 229 were injected with the flowering hormone GA. They were also drought stressed until the end of June. In the spring, there were repairs to orchard 207, where 371 trees were removed the previous fall. Also, 485 grafts were made, and the surviving 387 were planted in the holding area in September. The crop of 59 hectolitres yielded 57 kilograms of seed.

In the spruce orchard for the Peace River mid-elevation zone (212), 2723 trees were monitored for insects, disease, and rodents. A total of 167 weevil damaged tops were removed, and the young orchard was baited extensively for rodents. Replacement grafts were maintained in the holding area.

There were repairs to orchard 206 where 630 trees had been removed the previous fall. The trees were monitored for insects and disease and sprayed for spruce cone maggots and spruce cone rust. Rust brooms were removed, and rodents were baited. A crop of 30.2 hectolitres yielded 24.3 kilograms of seed.

The on-site research plantations were also monitored for insects and disease and baited for rodents. A spruce genecology trial was planted as well as some lodgepole pine to be used to screen for resistance to the fungus carried by the mountain pine beetle. Approximately 3500 white pine seedlings were also planted as part of a rust resistance screening trial, and a site was prepared for more to be planted in 2006. The *Ribes* garden was maintained, and white pine seedlings were inoculated in September. The ENA spruce trial was cut down in November using an excavator with a brush cutter head to prepare a site for a second-generation spruce progeny test.

Plate 46. The crew with the 2005 cone crop.

Plate 47. Margaret Lazar picking in orchard 208 (Bv Low Sx).

Plate 48. Mountain pine beetle attacked tree near the seed orchards.

Plate 49. Lauri Farrell tagging cone sacks.

Plate 50. Karen Turner picking in orchard 206 PG High Sx).

Plate 51. Topped trees in heavily rogued orchard 206 (Prince George High spruce).

Plate 52. The anti-aggregation pheromone Verbenone being used in an efficacy trial.

5.1.11 Kettle River Seed Orchard Co.

Rick Hansinger

SPU 1210

OBJECTIVES

Collect and store pollen from high-breeding-value parents from the PG, CP, and BV low seed planning units for SMP in 2006 and 2007.

RESULTS

Pollen collected from the Kalamalka research station breeding arboreta was applied to receptive female flowers at KRSO Pli PG low and Pli CP low orchards in May of 2005. These SMP'd cones will be harvested in Aug./Sept. 2006, and analysis of the number of seeds present in each cone and the number of filled seeds in each cone will provide seed set data. A small quantity of seed will also be available following extraction to contribute to the objective of supplying seed for the CP and PG seed planning units.

OUTPUT AND DELIVERABLES

Specific products produced as a result of this project were 100 ml of pollen for Pli PG low and 165 ml of pollen for Pli CP low. A pollen vacuum and small generator to facilitate collections were also purchased with partial funding from OTIP.

FINANCIAL

Actual expenditures for the project were $1649.50, and the approved expenditure was $2915.00. The reduction in project expense was due to the fact that there was only a small number of receptive female flowers to available for SMP, and the original estimate of pollen needed was high. As the orchard increases in productive capacity, additional pollen volume will be collected.

5.2 Technical Support Projects

5.2.1 Cone and Seed Pest Management – Interior Operations

Robb Bennett

This project covers operational expenses for the Interior seed pest management biologist's activities, including all expenses associated with lab, field, and office work. Included in this project are wages for one co-op student (one term) and auxiliary technical support (as needed) to assist with operational pest management trials, data analysis, and development of new operational techniques. Work related to this project was suspended in January 2006 when the incumbent, Dr. Ward Strong, moved to the Research Branch to take over the newly created FIA-funded Cone and Seed Pest Research Scientist position. Interviews of candidates for the vacant Seed Pest Management Biologist position are scheduled for late March 2006.

Between April 1, 2005 and 31 December 2005, the Interior Seed Pest Management Biologist and/or the co-op student performed the following services.

- Performed 164 site visits, pest surveys and identification, and damage predictions and assessments.
- Delivered 46 written pest-survey reports to orchard managers and other seed production personnel.
- Performed 33 other pest identifications and submitted management recommendations to Ministry of Forests and Range personnel.
- Dealt with 19 requests for information from members of the public.

Work continued on in-house and collaborative development of protocols for seed bugs, seed wasps, coneworms, mountain pine beetle, and other insects of importance to Interior cone and seed production. In summary, the Interior Pest Management Biologist:

- initiated, continued, or completed seven in-house pest management research projects,
- collaborated with university, government, and other research personnel on five other projects,
- assisted in the preparation of mountain pine beetle risk

assessment documents for PGTIS and Skimikin seed orchards, and
- assisted in creating post-harvest management protocols for coneworm-infested cones.

As well as providing training for biology co-op students and orchard technicians, the Interior Pest Management Biologist provided the following training experiences:
- six extension education presentations to grade school, college, and university students,
- four professional presentations — the Entomological Society of Canada (two) and the Forest Genetics Council (two),
- five pest management workshops for orchard staff, and
- numerous "tail-gate"-type extension presentations to operational personnel.

The following publications resulted from this project.

Strong, W.B. Submitted. Seasonal changes in seed reduction in lodgepole pine cones caused by feeding of *Leptoglossus occidentalis* (Hemiptera: Coreidae). Canadian Entomologist.

Strong, W.B. 2005. *Dioryctria* research in British Columbia. Canadian Tree Improvement Association Tree Seed Working Group News Bulletin 41: 2-6.

Jocelyn G. Millar, Gary G. Grant, J. Steven McElfresh, Ward Strong, Carline Rudolph, John D. Stein, and Jardel A. Moreira. 2005. (3Z,6Z,9Z,12Z,15Z) – Pentacosapentaene, a key pheromone component of the fir coneworm moth, *Dioryctria abietivorella*. Journal of Chemical Ecology 31 (5): 1229-1234.

5.2.2 Western Redcedar Pollen Monitoring, Saanich Peninsula and Sechelt

Joe Webber

SPU 0212

INTRODUCTION

Annual calculations for estimating a seedlot's GW include the contribution of female and male gamete. For pollen contribution, this also includes non-orchard sources and SMP. Methods of estimating pollen contamination are based on pollen monitoring and are described in Woods et al. 1996.

Currently, only coastal Douglas-fir and lodgepole pine (Prince George) seed orchards are species that are known to be at risk from contamination. However, the CF Standards also require levels of pollen contamination to be reported when a species is at risk. On the coast, this includes western redcedar, western hemlock, and Sitka spruce. Monitoring potential contamination of these species began in 2005. This report includes the second year (2006) of monitoring western redcedar pollen flight at Sechelt and on the Saanich peninsula.

METHODS

Pollen was monitored using the ministry-standard seven-day recorders (Webber and Painter 1996). Western redcedar pollen was monitored at the same five locations on the Saanich peninsula used to estimate annual Douglas-fir pollen flight. Cedar pollen was also monitored at two CanFor orchard locations and one off-site location at Sechelt. Two replicates were counted on each chart, and the total number of pollen grains were averaged for the two replicates and then divided by 44 mm^2 (the area of the chart counted) to represent the number of pollen grains per mm^2 for a 24-hour period.

RESULTS

Figure 6 shows the mean western redcedar daily pollen catch for five stations on the Saanich peninsula, and Figure 7 shows the mean daily pollen catch for three stations at Sechelt. In 2006, western redcedar pollen was captured on the first day (February 07) of monitoring on the Saanich peninsula and continued to an estimated date of February 26. It is likely that some pollen shed occurred later than February 26, but predominately the pollen captured was red alder, which is the same size and shape. At Sechelt, redcedar pollen shed ranged from the start of monitoring (February 07) to an estimated date of March 08. It is also likely that some western redcedar pollen was shed after March 08, but predominately the pollen captured was red alder.

To compare year-to-year variation in pollen production, total pollen load is calculated as the sum of daily pollen catch (grains/mm^2/day) over the monitoring period. Mean pollen load is shown in Table 7. Values for 2006 were about 25% of the levels observed in 2005, and the load in Sechelt was about twice that of the levels observed on the Saanich peninsula.

	2005	2006
Monitoring Location	Pollen Load (grains/mm²)	
Saanich Peninsula	114.8	33.3
Sechelt	241.8	64.9

Table 7. Mean western redcedar pollen load for two monitoring sites and two monitoring years.

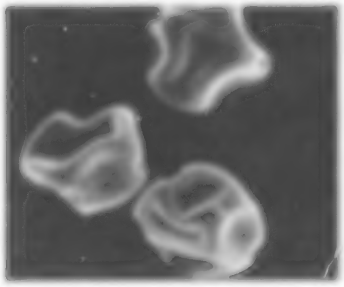


Plate 13. Red alder pollen.

Plate 14. Redcedar pollen.

Photos taken from Owens and Simpson 1981 and used with permission from the Ministry of Forests and Range (2006).

CONCLUSIONS

The magnitude and extent of western redcedar pollen on both the Saanich peninsula and at Sechelt are the greatest for any coastal species monitored. However, the error in counts will also be considerably higher because western redcedar is the smallest size (25 µ), and its shedding dates overlap with red alder pollen, which is about the same size and shape as western redcedar pollen.

At higher magnifications (x400), it is possible to distinguish western redcedar pollen from red alder. Cedar pollen has warty structures (orbicules) on its exine, and red alder has several pore structures. However, distinguishing the two on a Vaseline-coated chart is very difficult.

With the magnitude of pollen counts for western redcedar at both the monitoring sites, it is likely that some contamination exists. This is certainly true for 2005, when pollen capture levels were four times those observed in 2006. Whether this is a serious problem is not known. Certainly, any orchard clone sired with contaminate pollen should have a small positive effect over selfing. However, because the breeding value of contaminate pollen would at best be neutral, any contamination will have a negative effect on higher-breeding-value clones.

This is the second year for monitoring western redcedar pollen shed from surrounding indigenous stands on the Saanich peninsula and Sechelt. However, the pollen monitoring technique used for Douglas-fir may not be applicable for western redcedar. The actual monitors do an excellent job of capturing the pollen, but the charts coated with Vaseline make positive identification difficult, even with compound microscopes using x100 magnification. Even then, distinguishing between redcedar pollen and other species, principally red alder, will be difficult, and the errors associated with the counts will be higher.

LITERATURE CITED

Owens, J. N., and Simpson, S.J. 1981. Manual of conifer pollen from British Columbia conifers. Edited and reformatted by J.E.Webber (2006). BC Ministry of Forests and Range, Interm. Pub.

Webber, J. E., and Painter, R. A. 1996. Douglas-fir pollen management manual, 2nd Edn. Ministry of Forests and Range, Research Branch. Wkk. Pap. 02/1996. 91pp.

Woods, J. H., Stoehr, M. U., and Webber, J. E. 1996. Protocols for rating seed orchard seed lots in British Columbia. Ministry of Forests and Range, Research Program, Res. Report 06. 26pp.

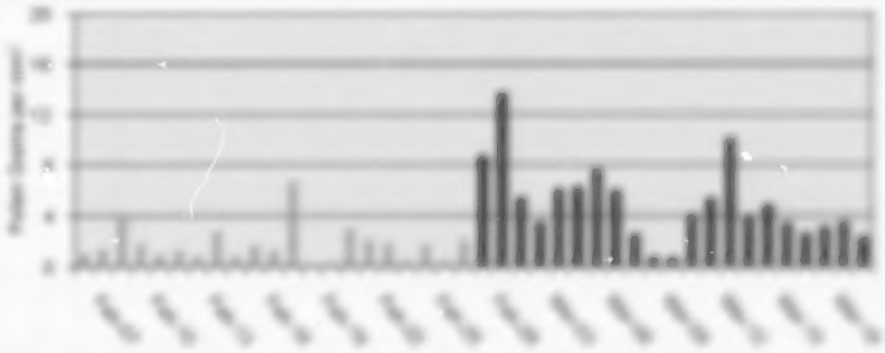


Figure 6. Mean daily western redcedar pollen catch (pollen grains/cm²/24 hr) from five stations on the Saanich peninsula. Black bars are predominantly redcedar (same size and shape of western redcedar pollen.

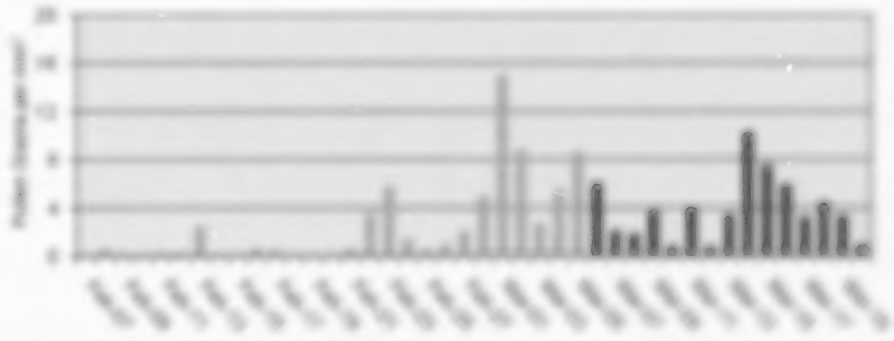


Figure 7. Mean daily western redcedar pollen catch (pollen grains/cm²/24 hr) from three stations at Sechelt. Black bars are predominantly redcedar (same size and shape of western redcedar pollen.

5.2.3 Douglas-fir and Western Redcedar Cone and Seed Insect Pest Monitoring Services to Coastal Conifer Seed Orchard Managers

Ross Bennett

Douglas-fir cone gall midge and western redcedar cone midge are the two most important insect pests in coastal British Columbia conifer seed orchards. Population levels of both these insects are routinely monitored each spring to determine damage potential and whether or not control options need to be used.

Orchard managers are now responsible for monitoring these insects on their sites. Formerly, Ministry of Forests and Range Seed Pest Management staff provided this service. This project was initiated to ease the transition process for coastal seed orchard managers.

In April 2005, Applied Forest Science Ltd. assessed cone/set samples from five of eleven coastal Douglas-fir seed orchards at four sites for levels of Douglas-fir cone gall midge. Reports of results (Table 8), including pest management recommendations, were sent electronically to respective orchard managers within 24 hours of receipt of samples. The remaining orchards were either unproductive in 2005 or were being monitored by on-site staff. Except for orchard 186, redcedar orchards were either monitored in-house in March 2006 by

orchard managers or were unproductive. At the time of this writing, the first of three cones samples from 198 had been assessed and no evidence of selfed or cone midge was observed.

Orchard	Yield	Orchard	Yield
116	0.0	198	7.4
148	0.0	199	15.0
160	0.0		

Table 6: Average cone yield per conelet counts (YIELD) for five of eleven coastal Mt. Douglas-fir seed orchards. Orchard 'Orchard Number' are above which control measures are usually appropriate. (SE = 0.0).

5.2.4 Development of Pollen Management Guidelines for Yellow-cone

Client: ***

Objective

Poor pollen quality at pollination time may be one of the principal factors responsible for the failure of low-elevation orchards to produce sufficient quantities of viable seed. To date, all assessments of pollen quality were based entirely on vitro testing, using pollen germination. These assessments should be interpreted as only an indication of pollen fertility. In this project, the actual fertility of low-elevation males is being confirmed through control pollinations of females in natural stands. Similarly, the level of fertility of low-elevation females is not known and is being examined through control pollinations, using high-quality pollen collected from natural stands.

Trials at a low-elevation seed orchard (Mt. Newton) and in natural stands at high elevation (Mt. Washington and Jordan River high elevation) have been completed, and the results were published in the 2004/2005 Project Report. The results indicate that low-elevation yellow-cone seed orchards are capable of producing viable seed. This is contrary to earlier reports that low-elevation seed orchards established on Vancouver Island are not capable of doing so.

Given the important consequences for the location and management of yellow-cone breeding and seed orchards, recommendations for their establishment should be based on more than one year's data. Furthermore, difficulties with environmental conditions and issues encountered during the first project introduced several factors that may influence, to a certain degree, the results of the trial.

A follow-up project at Mt. Newton seed orchard (low elevation) and Mt. Washington (high elevation) was therefore established in 2004 to deal with the above problems and to confirm the results in the first project through re-testing. An additional site at Jordan River low-elevation was included in the new project because it has produced good quality pollen in the past trials and has a good potential to produce viable seed. Control pollinations at all the above sites were completed in spring 2005. Cones will be collected and seed will be extracted in fall 2006, and the final results will be reported in spring 2007.

5.2.5 Operational Crown Management Trials on Various Orchards: Interior Spruce 'High-density' Seed Orchard 420 and Interior Douglas-fir Orchard 526

Client: ***

Objectives

The objectives of this project are to determine which crown management techniques are most effective in controlling vegetative growth to allow for safe cone collection and efficient orchard management. In addition, we are trying to determine the effects of various treatments on crop production. Trials are ongoing in the orchards, and treatments will be evaluated and refined based on survey results and observations.

Results

As we gain confidence in our crown management techniques, we have shifted our emphasis towards developing and testing practical, economical applications that are useful operationally.

Beginning in 2003, we implemented our approach to fruit treatments in the whole orchard. 2004 was the fifth year that these treatments were repeated. We usually conduct crop surveys to evaluate the effectiveness of the different treatments, but because 2003 was an unusually light crop year no surveys were conducted.

Weed management was initiated in Hongjiang No. 1 orchard (Orchard 1) as part of IPM (1997). Orchard 1(2) was established on the Beijing Road site in 2000. The trees are now well established and growing vigorously. This orchard is not yet in production.

We decided to begin managing cover structures within this orchard was still young. Most operational cover management takes place after an orchard has reached maturity and becomes difficult to handle. It would seem that controlling cover structures while an orchard is still developing would allow for more management options in the future.

Several different treatments have been initiated in orchard 1(2). These treatments will be evaluated based on survey results and will be modified accordingly.

Treatments applied in weeds in '03 orchard 1(2) in 2004. (See Table 3)

Currently four different treatments are being applied to weeds in our Orchard 1(2) cover structures (see Table 3).

We have been testing our current cover management techniques in orchard 1(2) for four field seasons. Because our survey results are based on four years worth of inconsistent flower crop data, we are reluctant to make any firm recommendations.

Orchard 1(2) is expected to produce a light flower crop in 2005. We will survey this crop and use the results to help evaluate our cover management treatments.

In 2005, we will continue to utilize our techniques in both orchard 1(2) and orchard 2(3) flower crop data.

Treatment	Location	Major Materials
1	Control row system	Control row system
2	Plant removal trial	Plant removal trial
3	Crop terminal trial (cattle)	Crop terminal trial (cattle)
4	Prune 100% of 2005 growth	Prune 100% of 2005 growth
5	Prune 100% of 2005 growth	Prune 100% of 2005 growth
6	Prune just below top shoot	Prune 100% of 2005 growth
7	Prune just above second shoot	No information

Table 2. Treatments applied in weeds in orchard 1(2) in 2004.

Treatment	Description	Prune Leader	Prune Branches	Trait
1	Weight control, [illegible] main	No info. in orchard. In check	Only if maintaining upright in 2 or 3 in. row size	No effect monitoring on specific trait
2	Plant removal	No data [illegible]	No data [illegible]	No data [illegible]
3	Operational apple pruning	Prune 100% current season growth. Not to exceed 3 in.	Remove 100% current growth to promote foliage effect	Prune to enhance branches undercutting 2 or 3 in. row size
4	Control	None	None	None

Table 3. Treatments applied in weeds in the [illegible] orchard.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	

[redacted]

[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

[redacted]

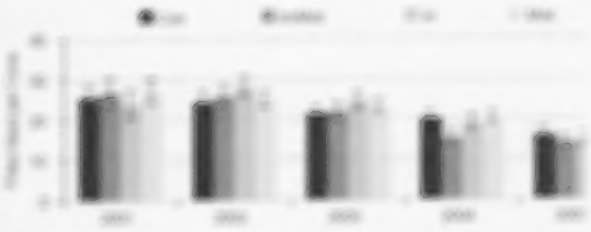


Figure 11. Mean ASI and pre-zone (±standard error) with mean predictions for each of four cultural blocks (2001–2005) at the Kalamalka hydroponic pre-seed orchard 307

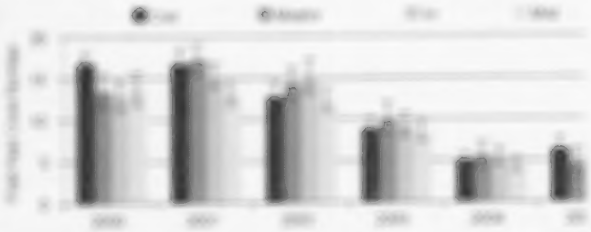


Figure 12. Mean first-year cone numbers (±standard error) for each of four cultural blocks (2000–2005) at the Kalamalka hydroponic pre-seed orchard 307

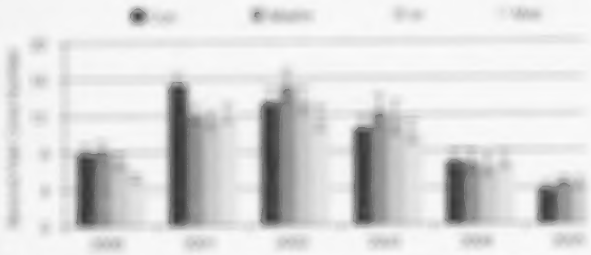


Figure 13. Mean second-year cone numbers (±standard error) for each of four cultural blocks (2000–2005) at the Kalamalka hydroponic pre-seed orchard 307

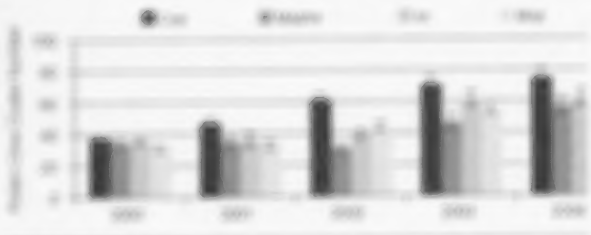


Figure 14. Mean yellow cone cluster numbers (±standard error) for each of four cultural blocks (2000–2006) at the Kalamalka hydroponic pre-seed orchard 307

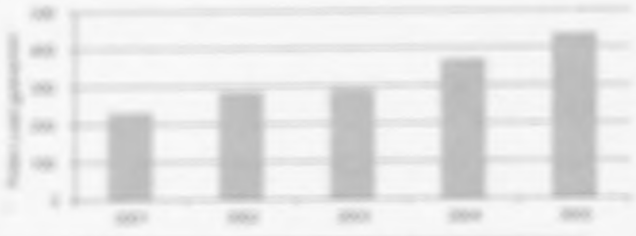


Figure 15. Pollen load (grains/mm²) summary (2001–2005) for the shedding period in the Kalamalka hydroponic pre-seed orchard 307

	2000	2001	2002	2003	2004	2005
Tech	na	4 140	6 615	4405	3 045	5480
Tech 28	na	208	74	46	456	1004
T-28 (Orig.)	na	15	3	2	34	28
pFOpen	na	518	553	414	341	429
pFOpen2	na	26	46	24	47	132
pFOC (Orig.)	na	17	26	15	28	30
pre-pollen	na	34.1	13.8	13.4	35.4	47.8

Tech+ num. mean hourly (+1 SE).
Tech28 num. mean hourly (−1 stderr, 1 SE).

pFOpen num. mean hourly (pFO).
pFOpen2 num. mean hourly (pFO, shown pFO+1).

Table 13. Heat and vapour pressure deficit sums (2000–2005) for the period of pre-pollination (mid-April to mid-May) in the Kalamalka seed orchard 307

	2000	2001	2002	2003	2004	2005
Tech	3809	4 145	6824	3 171	3 0 1 1	4 1 1 4
Tech 28	534	1 1 1 1	204	86	1 1 3	1 4 8 1
T-28 (Orig.)	9	56	12	2	16	51
pFOpen	1 1 1	1 0 8	1 0 1	4 1 6	1 0 5	1 4 7
pFOpen2	2 1	1 4 5	3 8	1 4	3 7	1 1 3
pFOC (Orig.)	1 4	1 4	2 7	2 1	2 6	1 4
pre-pollen	na	2 1 . 1	3 1 . 3	3 1 . 4	1 0 1 . 4	2 1 . 5

Tech+ num. mean hourly (+1 SE).
Tech28 num. mean hourly (−1 stderr, 1 SE).

pFOpen num. mean hourly (pFO).
pFOpen2 num. mean hourly (pFO, shown pFO+1).

Table 14. Heat and vapour pressure deficit sums (2000–2005) for the period of pollination (May 15–25) in the Kalamalka seed orchard 307

	2000	2001	2002	2003	2004	2005
Tech	1 2 1 7	1 0 0	1 6 0 1	1 0 4 8	1 0 5 8	1 5 0 6
Tech 28	1 1 3 6	1 4 8	1 0 1 1	1 4 4 5	1 4 8 1	1 1 1 5
T-28 (Orig.)	1 0	4 6	1 1 8	1 0 1	1 1 5	4 1
pFOpen	1 2 1	1 3 6	1 0 2 6	1 0 7	1 0 3	1 1 0
pFOpen2	1 2 8	1 4 1	1 4 5	1 4 5	1 4 8	1 5
pFOC (Orig.)	1 0	1 1	1 3 1	1 0 1	1 1 6	1 5
pre-pollen	na	1 2 . 8	1 1 . 4	1 1 . 5	1 6 . 1	1 4 . 1

Tech+ num. mean hourly (+1 SE).
Tech28 num. mean hourly (−1 stderr, 1 SE).

pFOpen num. mean hourly (pFO).
pFOpen2 num. mean hourly (pFO, shown pFO+1).

Table 15. Heat and vapour pressure deficit sums (2000–2005) for the period of fertilization and early embryo development (June 1–30) in the Kalamalka seed orchard 307

	2000	2001	2002	2003	2004	2005
Taum	5240	7017	7132	7173	5911	6062
Taum-24	559	1559	1014	1088	522	525
T-24-3(46)	15	56	178	98	229	15
VPDtaum	349	672	880	891	297	457
VPDtaum-3	20	174	135	211	11	28
VPD-T-3(46)	10	72	67	75	5	13
interpolation	na	40.9	20.4	93.3	108.3	51.9

Taum taum master insanity T-24)
Taum-24 taum master insanity T where T= (46)

VPDtaum taum master insanity VPD)
VPDtaum-3 taum master insanity VPD where VPD3=3

Table 56. Heat and vapour pressure deficit sums (2000-2005) for the period of seed cone differentiation (September 1-30) in the Kalamalka seed orchard 307.

5.2.8 Increasing Quality, Genetic Gain, and Quantity of Yellow-cedar Cuttings

Dan Carson, John Ogg, Craig Ferguson, John Russell

VPU 1113

INTRODUCTION

This project involves increasing the quantity and quality of high-value yellow-cedar cuttings for the coastal program. Objectives include:

1. providing the cultural treatments required to produce improved hedge production
2. enhancing hedge composition by replacing lower-genetic-value families and clones with newly tested improved clones.

2005/2006 HIGHLIGHTS

Hedges were heavily pruned in early 2005 and fertilized with 19-19-19. A second pruning occurred in June. The soil-based hedges were fertilized throughout July with 34-0-0, 0-0-22 plus sulphur +11.8 Mg; and then 11-51-0. The container hedges had APEX 16-5-11 in their media.

Sixteen rows of donors were removed from the soil-based hedging orchard to provide space for genetically improved clones. These clones will be planted in FY 2006/07.

In September donor stock nutrient levels were tested and all were low in micronutrients according to acceptable ranges except the donor stock in pots. However, all plants appeared healthy.

There were approximately 185 K from 13 K donors available for production this fiscal with an estimated GW of 10%.

Approximately 4200 cuttings from 49 selected clones were potted up into 1 gallon square pots, pruned, and placed in a greenhouse for new donor production. An additional 5000 cuttings were set from another 40 selected clones. The goal is to eventually produce 300 K cuttings from 6000 container-grown donors in a greenhouse composed of 50 selected clones.

Plate 55. Inspecting yellow cedar cuttings for donor production.

Plate 56. Yellow cedar soil based donor hedges.

Plate 57. Top pruning yellow cedar donors.

Plate 58. Potted yellow-cedar donors.

Plate 59. Potting up yellow-cedar cuttings for donor production.

5.2.9 Damage potential of *Leptoglossus occidentalis* on Sx, Lw, Pw, and Fdi

Ward Strong

L. occidentalis is a key pest that contributes to low seedset in Interior lodgepole pine seed orchards and also feeds on seeds of other conifer species. The damage potential of individual bugs on lodgepole pine is well known but is poorly characterized on other species. Knowledge of the impact of *Leptoglossus* on crop yield is required for rational management of this pest. One season's worth of data exists for Sx and Lw, but the effects of field densities of *Leptoglossus* on Pw and Fdi have never been determined. This study was designed to increase our knowledge of the impact of *L. occidentalis* on these four conifer species.

MATERIALS AND METHODS

Six Sx, two Lw, two Pw, and five Fdi orchards in the Interior of BC were selected. Six to 10 trees were randomly selected in each orchard. On each, one branch tip with four to five cones was enclosed in an insect exclusion bag. Bags were installed by mid-May before *Leptoglossus* became active in the orchards. Each branch was chosen so that an equal number of cones on a similar branch of the same tree was available for an unbagged treatment. Each orchard was monitored visually for *Leptoglossus* every week. Cones were to be harvested in early August for seed extraction and analysis.

RESULTS

Weekly monitoring indicated that *L. occidentalis* densities were very low into July. It was decided that the likelihood of gathering useful data was very low and did not justify the time and expense required to harvest cones, extract seed, X-ray and count filled and empty seeds, and tabulate and analyze the results. Thus this project was terminated before completion. It will be continued in 2006.

5.2.10 Effect of Selfing and Flowering Phenology on Seed Production in Yellow-cedar Seed Orchards

Oldrich Hak

SPU 1112

Results from a current study indicate that low-elevation yellow-cedar seed orchards are capable of producing viable seed (see Project Report 2004/2005). The study further shows that both low-elevation males and low-elevation females can produce viable seed. This is contrary to earlier reports that low-elevation seed orchards established on Vancouver Island are not able to do so. One possible answer to this discrepancy lies in the pollination method employed in each case. Open pollination was practiced in the early seed orchards at low elevation. Similarly, when open-pollinated cones were collected in the current study, they also produced empty seed. However, when control pollination was used, viable seed was produced. On the open pollination sites, there was no lack of pollen on either the tested trees or the surrounding trees. This suggests that there may be several unknown and untested factors responsible for the failure to produce seed.

The objective of this project is to test three possible causes for empty seed production in open-pollinated seed orchards: selfing, flowering phenology (timing on natural pollen shed vs. timing of female flowers receptivity) and insect damage.

The study is being carried out at two locations at two different time periods. The first trial was initiated at the Mt. Newton seed orchard in spring 2005, and the second trial will be initiated at the Western Forest Products seed orchard in spring 2006. Pollinations were completed at Mt. Newton in winter 2006, and at Western Forest Products the pollinations will occur in winter 2007. Cones will be collected and seed extracted one year after each pollination.

5.2.11 Crown Pruning Technique for North Okanagan Lodgepole Pine Seed Orchards.

Chris Walsh and Joe Webber

SPU 0720, 2005

As orchards mature, crown form eventually becomes either too high or too bushy to manage effectively. In general, tree height beyond 5-6 m requires some form of topping and pruning of lateral branches that extend into the rows to allow both tractor and picker access. Experience from pruning treatments applied to lodgepole pine at Prince George TIS (Stoehr et al. 1995) suggests that cone production (both seed and pollen cones) will drop immediately after pruning but can return to pre-treatment levels within three years. Seed set was not studied and there still remain concerns about topping, mostly related to increased selfing.

Most north Okanagan lodgepole pine seed orchards are now at the age when crown management activities are required. Lodgepole pine seed orchard 230 at Kalamalka was chosen for this pruning trial because the seed from this orchard was not in high demand and the trees are now at an age (12-15 years) and height (4-6 m) when crown management must be considered. In 2004, three blocks were selected and top pruned to three heights: control (no topping), moderate (3.5-4.0 m) and severe (2.5-3.0 m). In addition, each topping regime was lateral pruned for two types of access: tractor (remove only laterals extending into the row) and picker (remove extending and upper crown laterals to improve crown access).

Before crown pruning, 20 trees were randomly selected for each lateral pruning treatment (two from each of three blocks). Estimates of whole-tree cone numbers were recorded and the number of first- and second-year cones was sampled on major whorl branches in the upper and lower crowns. For cone analysis, a sample of second-year cones from the upper and lower crown with and without insect protection was collected. Finally, a sample of cones from the upper and lower crown was collected for cone dry weight determination.

In the fall of 2004, prior to pruning, all treatment trees were measured for tree height and diameter and assessed for both tractor and picker access. Complete details for 2004 and 2005 pruning treatment data are available in the 2005 final report for OTIP 0720. This report summarizes the cone and seed yield data prior to pruning (2004) and the year following pruning (2005).

SEED CONE NUMBERS

Figure 17 shows estimates for whole tree seed-cones counts for each of the control (Con), moderate (Mod), and severe (Sev) topping heights and picker (Pick) and tractor (Tract) lateral pruning treatments for the years prior to pruning (2004) and following pruning (2005). Figure 18 shows actual seed cone counts for major whorl branches from each of the three topping blocks in the upper and lower crown. Seed cone numbers varied among topping blocks and sampling position within the crown, with higher numbers in the top, more vigourous part of the crown. Estimates of whole-tree seed cone counts for the year following pruning (2005) dropped to less than one-third of 2004 values. This was expected because pruning in 2004 removed a substantial number of first-year cones. We also expect the number of seed cone counts in 2006 to be substantially lower as well because differentiated seed cones in the 2004 shoots were removed.

SEED CONE YIELDS

Figure 19 shows the number of filled seed per cone (FSPC) from insect-protected cones only. Insect predation was substantial with about 10 seeds per cone lost (see final report for data). Again, variation in filled seed per cone occurred between topping and lateral pruning treatments, which were considerably less the year following pruning (2005). Crown position also affected seed yields (Figure 20). Seed cones from high in the crown produced more seed and the actual number varied among topping blocks. After pruning (2005), the differences in upper and lower crown yields were considerably less (Figure 20), suggesting that pollen supply to the upper and lower crown may have been more uniform after crown pruning. However, mean seed-cone yields the year following pruning (2005) were about 5 FSPC lower than the yields before pruning (2004). This may indicate a drop in production due to selfing, and subsequent years' observation will determine the magnitude of year-to-year variation.

CONE MASS

Figure 21 shows the cone dry weights for each of the three topping blocks for cones in both the upper and lower crowns. There was little variation between

cone dry weight in either the topping blocks or crown position before pruning (2004). However, after pruning (2005), cone dry weight from the lower crown was substantially higher with the highest dry weights recorded in the lower crown of the severe topping treatment. A similar trend is also apparent for upper crown cone dry weights but not to the same extent as lower crown cones. This may suggest that pruning has re-invigourated crowns and that the effect is more apparent in the lower crown.

CONCLUSIONS

Data collected for the first year after crown pruning produced expected results for fewer cone numbers. However, the lower yield per cone was not expected. This may simply be a year-to-year variation the magnitude of which will be determined by observations in subsequent years. We expect the number of cones produced in 2006 will also be lower simply because pruning in 2005 removed shoots with differentiated cones. Finally, the substantial increase in cone dry weight from lower crowns the year following pruning suggests that crown vigour is improving. If this is the case, then we should begin to see higher cone numbers in 2007 and certainly in 2008.

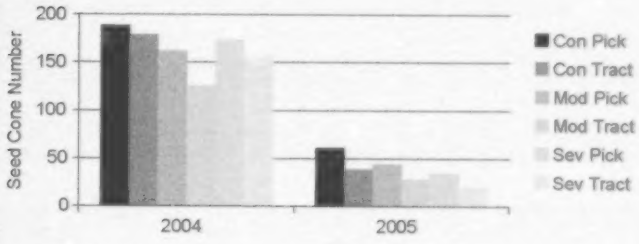


Figure 17. Whole tree seed cone estimates by topping height and lateral pruning treatments.

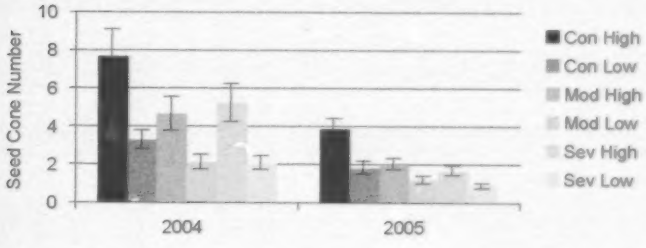


Figure 18. Mean branch seed-cone counts (±standard error) by topping height and crown position.

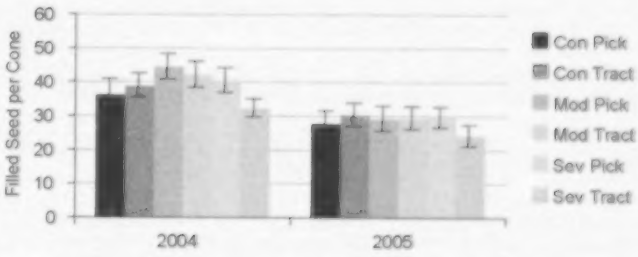


Figure 19. Mean filled seed per cone (±standard error) by topping height and lateral pruning treatment for insect protected cones only.

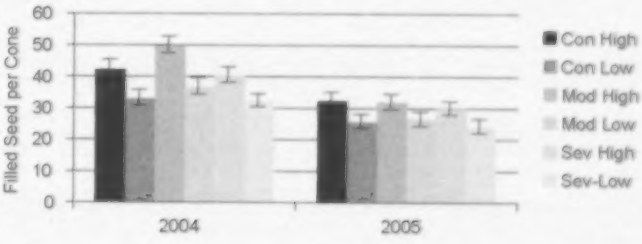


Figure 20. Mean filled seed per cone (±standard error) by topping height and crown position for insect protected cones only.

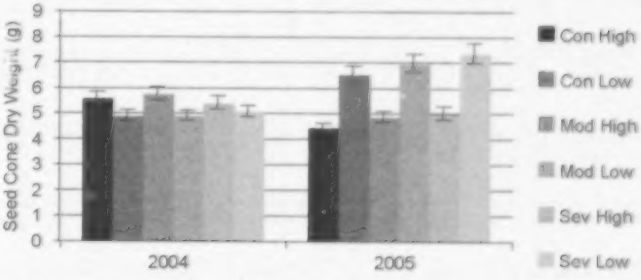


Figure 21. Mean seed cone dry weight (±standard error) by topping height and crown position for insect protected cones only.

5.2.12 Western Hemlock/Sitka Spruce Pollen Monitoring, Saanich Peninsula,

Joe Webber, ProSeed Consulting

SPU 0313

Annual calculations for estimating a seed lot's GW include female and male gamete contribution. This includes non-orchard sources of pollen (contamination). Methods to determine pollen contamination are available (Woods et al. 1996 and Woods 2005) and based on pollen monitoring.

The ministry standard for monitoring pollen cloud density uses seven-day recorders mounted on rotating platforms at 3 m height (Webber and Painter 1996). Daily pollen catch is expressed as the number of pollen grains per mm² for a 24-hour period and sampled at five pollen monitoring stations located over the north Saanich peninsula. These are the same five locations used by the Ministry of Forests and Range to determine annual Douglas-fir pollen cloud density.

In 2005, WFP, Saanich Seed Orchards also monitored western hemlock and Sitka spruce pollen in orchards 170 and 172 respectively. Microscope slides coated with petroleum jelly are mounted vertically on a wind vane platform at about 2 m height. Pollen catch is also expressed as grains/mm² for a 24-hour period.

Figure 22 shows the daily western hemlock pollen cloud density values averaged over the five Saanich peninsula stations. Figure 23 shows the daily Sitka spruce pollen cloud density values averaged over the same five stations. In 2005, the mean western hemlock pollen shed on the Saanich peninsula ranged from mid-March to the end of April with the peak pollen shed occurring on April 26, 2005.

For estimating potential contamination, the extent of western hemlock pollen shed is expressed as total pollen load (grains/mm²) summed over the shedding period. For western hemlock, pollen load for the period of March 15 to May 02, 2005 was 9.2 grains/mm². The regional pollen load value for the receptivity period of orchard 170 (March 23 to April 14, 2005) was 1.3 pollen grains/mm².

Pollen monitoring values for WFP orchard 170 (IN) during the receptivity period of March 23 to April 14, 2005 was 6.0 grains/mm². WFP also monitors pollen cloud density outside of the orchard (OUT). Pollen load for OUT over the same period was 0.9 grains/mm², respectively. The ratio of OUT/IN (15%) provides an estimate of the potential pollen contamination.

The corresponding estimate of pollen load using regional monitoring data (OUT) for the same receptivity period of orchard 170 was 1.3 grains/mm². The ratio of OUT/IN using this data estimates pollen contamination at 21.7%.

Figure 23 shows the daily Sitka spruce pollen cloud density values averaged over the five Saanich peninsula stations. In 2005, the mean Sitka spruce pollen shed on the Saanich peninsula ranged from late March to early May, 2005 with peak shedding occurring on April 14.

Sitka spruce pollen load from regional pollen monitors for the period of March 15 to May 02, 2005 was 1.6 grains/mm². The regional pollen load value for the receptivity period of orchard 172 (April 21 to May 02, 2005) was 0.3 grains/mm².

Pollen monitoring results for WFP orchard 172 (IN) during the receptivity period of April 21 to May 02, 2005 was 1.8 grains/mm². The corresponding value for monitoring outside of the orchard (OUT) was 0.8 grains/mm². The ratio of OUT/IN (44%) is the estimate of potential pollen contamination at the WFP western hemlock orchard 172.

The corresponding value for regional monitoring data (OUT) for the same period was 0.3 grains/mm². Using the orchard estimate (IN) of 1.8 grains/mm², the ration of OUT/IN would yield an estimate of 16.7% pollen contamination.

CONCLUSION

The pollen counts for western hemlock and Sitka spruce are considerably lower than those observed for Douglas-fir. For example, regional pollen load during the receptivity periods of WFP Douglas-fir orchard 166 in 2005 was 4.6 grains/mm². The corresponding pollen load within orchard 166 was 96.3 grains/mm². This represents a potential contamination of 4.8%.

This is the first attempt to monitor western hemlock or Sitka spruce pollen both regionally or within any coastal seed orchard site. While the data do provide some estimates of potential pollen contamination for these two species, they are based on one year's observations only. The levels of regional and within-orchard pollen cloud density were both relatively low, but we do not know the extent of year-to-year variation in both orchard and regional pollen cloud density.

Finally, the comparison of regional monitor counts (seven-day recorders) and orchard slide counts are not strictly comparable, since the trapping efficiencies of the two have not been compared.

REFERENCES

Webber, J.E., and Painter, R.A. 1996. Douglas-fir pollen management manual. 2nd Edn. BC Min. For., Res. Br. Wok. Pap. 02/1996. 91pp.

Woods, J.H., Stoehr, M.U., and Webber, J.E. 1996. Protocols for rating seed orchard seed lots in BC Min. For., Res. Prog., Res. Report 04. 26pp.

Woods, J. 2005. Methods for estimating gamete contributions to orchard seed crops and vegetative lots in British Columbia. BC Min. For. Range, Res. Br., Tech. Rep. 025. 17pp.

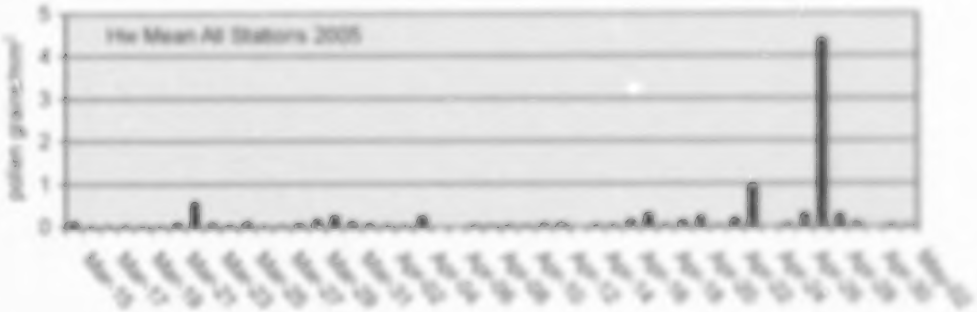


Figure 22. Western hemlock pollen shed on the Saanich peninsula, 2005 (mean of five stations).

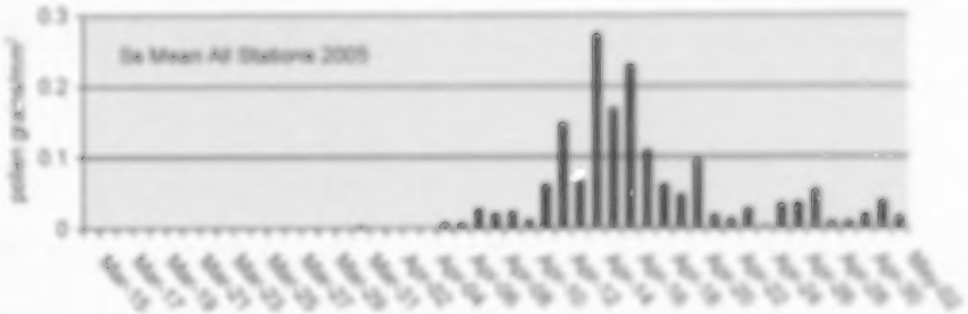


Figure 23. Sitka spruce pollen shed on the Saanich peninsula, 2005 (mean of five stations).

6.0 Extension and Communications

6.1 Extension Technical Advisory Committee (ETAC) Subprogram

Diane Douglas

ANNUAL ETAC MEETING

The annual ETAC business meeting was held at Cowichan Lake Research Station on November 22, 2006. A five-year extension plan for ETAC was initiated as a planning and budgeting process.

PUBLICATIONS

http://www.for.gov.bc.ca/hre.html

Extension Note 1: Benefits of Using Selected Reforestation Materials was printed.

Extension Note 7: The Reproductive Biology of Lodgepole Pine by Dr. J. Owens was published and printed.

Tree Improvement in BC (a six-page brochure) was published.

A poster, *The Tree Improvement Cycle in BC*, was developed and will be available in a variety of formats next year.

WORKSHOPS

An Extension Planning Workshop facilitated by Kathie Swift and Shawn Morford of FORREX was held in Vernon in June, 2006. An ETAC extension plan was developed for the committee and has been key to the development of the extension program.

Dr. Joe Webber led a Crown Management Workshop on November 4, 2006. Interior seed orchardists and seed users from Alberta attended an indoor training session, followed by an opportunity to visit Kalamalka and PRT Seed Orchards. The 28 attendees were very appreciative of the opportunity to attend and participate in the workshop.

A Coastal Pollen Management Workshop was held February 23 and 24, 2005 at Western Forest Products in Saanich with 25 people in attendance. Dr. Joe Webber, Ulrich Hak, and Dr. Patrick von Aderkas gave presentations. Lab and field aspects of pollen management were included in the workshop.

Plate 40. Crown management workshop led by Dr. Joe Webber, November, 2005.

Plate 41. Crown pruning workshop, November, 2005.

Plate 42. A presentation by Dr. Joe Webber at the coastal pollen management workshop February, 2005.

Select Seed Orchards
In the Ground and Growing

Appendix 3 FY22 Seed Planning Unit

[redacted]							

Synonyms of Time Quantum

[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

Appendix 3 Discussions by Tree Species

CONIFERS	ABBREVIATION	PAGE LOCATIONS
western redcedar	Cw	20, 21, 23-25, 37-39
yellow-cedar	Yc	30, 24, 25,40, 46-48
Douglas-fir	Fdc	5, 20, 21, 24, 37, 39
Interior Douglas-fir	Fdi	13, 30, 31, 40, 41
amabilis fir	Ba	
western hemlock	Hw	7, 20-22, 25, 37, 51, 52
western larch	Lw	15, 27
lodgepole pine	Pli	27-30, 32, 34, 37, 42-45, 48, 49, 53
western white pine	Pw	11, 23, 25, 27
Sitka spruce	Ss	4, 5, 7, 11,20-23, 37, 51-52
spruce hybrid (interior spruce/Ss)	Sx	34, 34, 35, 40-42
ponderosa pine	Py	16
HARDWOODS		
hybrid poplars	Ax	19
paper birch	By	17, 18
PEST		
Caloscypha fulgens		56
Fusarium		56
Sirococcus		56
Diorygtria abietivorella		36, 37
Seed chalcids		56
Leptoglossus occidentalis		36, 37

Appendix 4 Authors and Species Topic

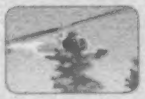
AUTHOR	SPECIES/DISCUSSION	PAGE
Aitken, Sally	Gene Conservation	4, 5
Ashley, Valerie	Fdi, Lw, Sx	13-15
Bennett, Robb	Cone and Seed Pests	36, 37, 39, 40, 56
Berger, Vicky	Pli	16-18
Bird, Keith	Fdc	5
Brown, Patti	Fdc, Hw, Pw, Yc, Cw	23, 24
Carlson, Mike	Pli	16-18
Cartwright, Charlie	Hw, Ss	7, 8
Cox, Keith	Pw, Sx	34, 35
Crowder, Tim	Fdc, Pw, Ba, Hw	24, 25
Douglas, Diane	Extension	53
Ferguson, Craig	Cw, Yc	9, 10, 46, 47
Giampa, Gary	Sx, Lw, Pli	40-42
Graham, Hilary	Pli, Fdi	30, 31
Hak, Oldrich	Hw, Yc	40, 48
Hansinger, Rick	Pli	36
Heeley, Tia	Sx, Pli, Fdi	28, 29
Hollefreund, Clint	Fdc	5, 6
Hooge, Bonnie	Fdi, Sx, Lw	13-15
Hunt, Rich	Pw	11, 12
Jaquish, B.	Fdi, Sx, Lw	13-15
King, John	Ss, Sx, Pw	7, 11, 12
McAuley, Leslie	SPAR	2, 3
Murphy, John	Pli	16-18
Painter, Roger	Program Management/Extension	19-20
Phillips, Giselle	Fdi, Sx, Lw	13-15
Pieper, Greg	Pli, Sx	32
Pomeroy, Dave	Ss, Pw	7, 11, 12
Rudolph, Dan	Pw, Fdc	26, 25
Russell, John	Cw, Yc	9, 10, 46, 47
Stoehr, Michael	Fdc, Pli, Sx	5, 6
Strong, Ward	Leptoglossus	48
Van Niejenhuis, Annette	Cw, Fdc, Hw, Ss	20-22
Wagner, Rita	Pli, Sx	32, 33
Walsh, Chris	Pli, Sx, Lw, Pw	27, 28, 43, 44, 49-52
Webber, Joe	Pli	43, 44, 49-52
Woods, Jack	Program Management/SelectSeed	1
Xie, Chang-Yi	Hardwoods	12, 13

Appendix 5 Author Contact List

CONTRIBUTOR	AFFILIATION	TELEPHONE NUMBER
Aitken, Sally	UBC	604-822-6020
Ashley, Valerie	MoF	250-260-4753
Bennett, Robb	MoF	250-652-6593
Berger, Vicky	MoF	250-260-4767
Bird, Keith	MoF	250-749-6811
Brown, Patti	CFP	604-885-5905
Carlson, Michael	MoF	250-260-4767
Carson, Don	MoF	250-749-6811
Cartwright, Charlie	MoF	250-387-6477
Cox, Keith	MoF	250-835-8626
Crowder, Tim	TimberWest	250-652-4211
Douglas, Diane	MoF	250-356-6721
Draper, Dale	MoF	250-387-3179
Elmslie, John	Winton Global	250-960-3933
Ferguson, Craig	MoF	250-749-6811
Giampa, Gary	MoF	250-549-5576
Graham, Hilary	PRT	250-546-6713
Hak, Oldrich	Contractor	250-727-3989
Hansinger, Rick	KRSO	250-493-6373
Heeley, Tia	VSOC	250-542-0833
Hollfreund, Clint	MoF	250-952-4127
Hooge, Bonnie	MoF	250-963-8416
Jaquish, Barry	MoF	250-260-4766
King, John	MoF	250-387-6476
Murphy, John	MoF	250-260-4767
Ogg, John	MoF	250-749-6811
Owens, John	UVic	250-652-4211
Painter, Roger	MoF	250-356-9276
Phillips, Giselle	MoF	250 260 4756
Pieper, Greg	Tolko	250 546-2296
Ponsford, Dave	MoF	250 387-1058
Rudolph, Dan	MoF	250-757-2015
Russell, John	MoF	250-749-6811
Stoehr, Michael	MoF	250-356-6209
Strong, Ward	MoF	250-549-5696
Van Neijenhuis, Annette	WFP	250-652-4023
Wagner, Rita	MoF	250 963-8416
Walsh, Chris	MoF	250-260-4777
Webber, Joe	MoF	250-537-8871
Wigmore, Bevin	TimberWest	250-652-4211
Woods, Jack	SelectSeed	250-748-9579
Xie, Chang-Yie	MoF	250-387-8911

Selection 1
Select the healthiest and fastest-growing trees in the forest.

Collection 2
Seed and scions collected from selected trees in the forest.



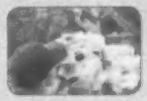
Clonebank/Breeding Arboretum 3
Graft scions for preservation and breeding of selected trees.

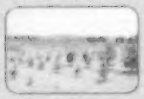
Progeny Testing 4
Offspring of selected trees grown and compared in forest environments.

Reselect Parents 5
Best parent trees selected based on offspring performance.

Collect and Graft Scions 6
Best offspring-tested parent trees grafted for seed orchards.

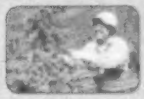
Breeding 7
Intercrossing of best parents for next generation of selection.



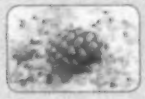


A **Seed Orchard Establishment**
Best offspring-tested parent trees grafted and planted in seed orchards.

B **Pollination**
Natural and supplemental pollination for seed production.



C **Seed Production**
Mature seed cones are collected.



D **Cone and Seed Processing, Testing, Registration**
Cone and seed processing, testing, registration, storage, and pretreatment.

E **Seedlings**
Seedlings produced in forest seedling nurseries.

F **Reforestation**
Seedlings planted, plantations maintained.

FGC

FOREST SERVICE · BRITISH COLUMBIA ·

BRITISH COLUMBIA